Model Commissioning

Plan and Guide Specifications

Sponsored by
US Department of Energy
Seattle Regional Support Office
800 5th Ave. Suite 3950
Seattle, WA 98104

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Prepared by:
Portland Energy Conservation, Inc. (PECI)
921 SW Washington, Suite 312
Portland, OR 97205
503-248-4636, Fax 503-295-0820

Version 2.02

March 1997

MASTER

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Acknowledgments

This project was funded through the USDOE contracts DE-AP51-96R020748 and DE-AP51-95R020661. Appreciation is extended to Arun Jhaveri of USDOE, Seattle Regional Support Office for his vision for the project and to Anne Sprunt-Crawley, USDOE FEMP (Federal Energy Management Program) headquarters, for her ongoing support. This project was the synthesis of our own experience and the ideas and experience of a number of commissioning experts, whose contributing documents are listed in the Overview. I acknowledge the insightful review and comments of Version 1 by Mike Kaplan of Kaplan Engineering and Phoebe Caner of the University of Washington. The invaluable contributions, review and support of my colleague, Tudi Haasl, are also deeply appreciated.

—Karl Stum

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Model Commissioning Plan and Guide Specifications

Overview

Commissioning. Commissioning (Cx) is a systematic process of ensuring that building systems perform interactively according to the design intent and the owner's operational needs. This is achieved beginning in the design phase by documenting the design intent and continuing through construction, acceptance, and the warranty period with actual verification of performance, operation and maintenance (O&M) documentation verification and the training of operating personnel.

Objectives

The objectives of the Model Commissioning Plan and Guide Specifications are to:

During design:

1. Ensure that the design team applies commissioning concepts to the design, e.g., clear and complete design intent documentation is developed and commissioning-focused design reviews are conducted.
2. Ensure that the design team prepares commissioning specifications and a commissioning plan for inclusion in the bid construction documents.

Meeting these objectives during design prepares the way so that the:

- Contractors can accurately bid the commissioning work.
- Contractors can understand how to efficiently execute the commissioning process.
- There is a systematic, efficient and enforceable method to accomplish the commissioning objectives.
- The commissioning objectives are met. At the building level these objectives include:
 - Ensure that applicable equipment and systems are installed properly and receive adequate operational checkout by installing contractors.
 - Verify and document proper performance of equipment and systems.
 - Ensure that O&M documentation left on site is complete.
 - Ensure that the Owner's operating personnel are adequately trained.

General Overview

The *Model Commissioning Plan and Guide Specification* is not intended to be a workbook or a manual on commissioning. Little background information on commissioning approaches, narrative of the commissioning process, costs and benefits of commissioning, etc. is included. This information is readily available in a number of other publications. The model plan and guide specifications were developed to provide those who are ready to incorporate commissioning, boilerplate-type language, content, format and forms for specifying and executing the commissioning process, so that they do not have to start from "scratch."

The *Model Commissioning Plan and Guide Specifications* generally follow the guidelines described in the ASHRAE document, *The HVAC Commissioning Process* referenced at the end of this overview. A number of other documents were used, as referenced, along with the authors' own commissioning experience. The *Model Commissioning Plan and Guide Specifications* were developed to be as generic as possible— though they were tailored to fit the management structure of General Services Administration (GSA), Region 10— for conventional design / spec / bid construction. Refer to the introduction to Part III Commissioning Guide Specifications for additional details on management structure assumptions.

The term “model” in model commissioning plan means that the commissioning plan is intended to be broadly representative of what a commissioning plan should actually look like. The commissioning plans have been developed to be somewhat generic and yet be structured so as to be easily adaptable to specific projects.

The term “guide” in guide specifications means that the commissioning specifications represent recommended language intended to be broadly applicable. The architect and design engineer, along with the commissioning agent, adapt this guide specification to incorporate commissioning into their projects.

The model plan and guide specifications were developed for larger, more complex projects and systems. A more streamlined commissioning approach may be appropriate for buildings less than 70,000 sf with simple equipment (packaged equipment and controls, no building automation system, etc.).

Document Organization

The Model Commissioning Plan and Guide Specifications are comprised of the following four separate documents designated as “parts.”

- Part I. *Commissioning Requirements—Design Phase*
- Part II. *Model Commissioning Plan—Design Phase*
- Part III. *Commissioning Guide Specifications*
- Part IV. *Model Commissioning Plan—Construction Phase*

A brief description of each part follows:

Part I. Commissioning Requirements—Design Phase

The *Commissioning Requirements—Design Phase* are requirements relating to commissioning which the design team is required to carry out during the development of the contract documents. The requirements include a listing of the responsibilities for each member of the design team. In addition, for perspective it lists the responsibilities of all players during the construction phase. This document is intended to be included in the request for proposal (RFP) for architectural/engineering (A/E) services and for prospective commissioning agents, after having the appropriate check boxes and blanks filled in by the Owner. The list of requirements provide little detail, as they point to the fully explained procedures in the *Model Commissioning Plan—Design Phase*. In the Appendix to Part I, a sample RFP for a commissioning agent is provided. (Part I length: Requirements and appendices 31 pgs)

Part II. Model Commissioning Plan—Design Phase

The *Model Commissioning Plan—Design Phase* guides the commissioning activities during the design phase. It provides details of responsibilities called out in Part I, *Commissioning Requirements—Design Phase* for the architect, design engineers, commissioning agent, construction and project managers. The plan describes the duties of the A/E team and commissioning agent in developing the site-specific

commissioning specifications and for developing the first two drafts of the *Commissioning Plan—Construction Phase*. (Part II length: Plan and appendices 85 pgs)

Part III. Commissioning Guide Specifications

The commissioning guide specifications contain recommended language that describes both the requirements and the process to incorporate commissioning into the construction specifications. All divisions and sections that relate to commissioning include language to ensure that the contractors are clearly informed regarding their commissioning responsibilities. Adequate explanation of the commissioning process is also provided. In addition, prefunctional checklists and sample functional tests are included for the many common types of equipment and systems. (Part III length: Specifications ~132 pgs, prefunctional checklists ~100 pgs, functional tests ~126 pgs)

Part IV. Commissioning Plan—Construction Phase

The *Commissioning Plan—Construction Phase* is developed in draft form for the specific project during the design phase. During the design phase, the plan provides direction for the development of the site-specific commissioning specifications by the design team. During the construction phase, the plan provides direction for the commissioning tasks during construction. The plan focuses on providing support to the specifications and provides forms for application of the commissioning process. (Plan 16 pgs, forms 40 pgs)

Limitations

The Model Commissioning Plan and Guide Specifications do not cover specific commissioning testing requirements, checklists, or sample functional tests for the following. However, the process described herein, particularly in Section 17100, can apply to any equipment.

- Plumbing fixtures and equipment (other than heating and cooling water piping)
- Architectural features, finishes and hardware
- Interstitial cavity differential pressure gradients and moisture control
- Laboratory fume hoods and clean rooms
- Medical gas systems
- Measurable equipment sound and vibration control
- Electrical system components, sometimes covered by municipal inspections (grounding, transformers, switchboards, etc.)

Document Use

All documents have been provided on electronic disk for adapting, as explained in a later section. All four parts of the *Model Commissioning Plan and Guide Specifications* are intended to be used together during the design phase. If formal commissioning is not going to be incorporated during design, some of the commissioning concepts and tasks from Parts I and II could still be assigned to the design team. At minimum, the development of commissioning specifications for construction sections should be completed during design (*Part II, Commissioning Plan—Design Phase, Task 6*).

The recommended procedure for using the *Model Commissioning Plan and Guide Specifications* starts in or before the design phase, as follows:

Step 1. Before beginning design, the owner uses the commissioning agent solicitation documents in Appendix 1 of *Part I, Commissioning Requirements—Design Phase* to obtain the services of a commissioning agent. If this commissioning agent is engaged before design, the commissioning agent contract may need to be structured in two parts: one for the design phase and one drawn up later for the construction phase, once more is known about what systems will be in the building. Also, the owner may choose to have the construction phase commissioning agent hired under or be part of a construction management contractor, who may not be known during design.

Step 2. The commissioning agent and the owner fill out an initial draft of the *Commissioning Plan—Design Phase* (in Part II).^{*} Full directions are provided at the beginning of the plan for filling this out.

Step 3. The commissioning agent and the owner edit and adapt the *Commissioning Requirements—Design Phase* (in Part I) to be appropriate for the specific project.^{*}

^{*}If the commissioning agent is not formally engaged yet, the owner may complete this step on their own or may use the temporary consulting services of a commissioning agent or qualified engineer.

Step 4. The adapted *Commissioning Requirements—Design Phase* (Part I) and the filled-in *Commissioning Plan—Design Phase* (Part II), along with the as-is *Guide Specifications* (Part III) and as-is *Commissioning Plan—Construction Phase* (Part IV) are provided to the design firms in the solicitation for their services. Due to the size of these documents, it may be appropriate to distribute the documents after short listing is completed.

Step 5. In the design contract, the owner explicitly includes Parts I and II (*Commissioning Requirements—Design Phase* and *Commissioning Plan—Design Phase*) and refers to Part III and Part IV (*Guide Specifications* and *Commissioning Plan—Construction Phase*), as reference material.

Step 6. The owner engages a commissioning agent per Step 1, if not already completed.

Step 7. The selected design firm uses Parts I, II, III and IV during design as they follow the *Commissioning Plan—Design Phase* (Part II). The design team develops clear design documentation, incorporate commissioning specifications into the main building specifications using the guide specifications (Part III), and create two drafts of the *Commissioning Plan—Construction Phase*, specific to this project. The owner participates in this process according to the design-phase plan.

Step 8. The owner includes the second draft of the *Commissioning Plan—Construction Phase* (Part IV) along with the construction specifications that include commissioning specifications in the construction bid documents.

Step 9. The owner makes sure all contract language referring to testing, completion milestones, etc. are consistent with the commissioning specifications in the bid documents.

Step 10. The owner engages a commissioning agent per Step 1, if not already completed.

Step 11. The commissioning process is executed per the bid commissioning specifications and commissioning plan.

The following graphic illustrates the above process.

Commissioning (Cx) Contract Document Development

Copyright

This work is in the public domain and may be copied and distributed at will. However, once files have been edited they should have the reference to PECO and USDOE removed from the footers. When appropriate, referencing the source of the documents would be appreciated.

Electronic Format

All parts of the Model Commissioning Plan and Guide Specifications have been included on diskette for modification, adaptation and use, as necessary. The commissioning plans are provided as one document each. The appendices of each plan are included as separate documents. Each of the forms in the Appendix of the construction phase commissioning plan is included as a separate document file, as is each individual section of the specifications. The file format is Word 6.0 for Windows 3.1 with a few forms in Excel 5.0 for Windows. Filenames are included in the footer for reference in all hard copies. For ease of access, all electronic files have been archived into two master files that will automatically create and extract the files into seven directories, as described in the *readme_.txt* file.

Order of Electronic Files

The following list of files corresponds to the order of the documents in the hardcopy of the *Model Commissioning Plan and Guide Specifications*. Preceding the file listing for each section is the subdirectory where the files are contained, after being expanded.

Directory: \DESIREQR.PT1 (The underscore in the file name extension is a place holder for the version number.)

Model Commissioning Plan and Guide Specifications Overview.....ALL_OVR.VU_

Part I: Commissioning Requirements—Design Phase.....DES_REQR.V__

Appendix 1: Solicitation for Commissioning Agent Services.....CA_RFP.0__

Exhibit 4: Commissioning Firm Experience (2 files).....CA_INFOR.FRM

.....CA_EXPER.XLS

Directory: \DESIPLAN.PT2

Part II: Model Commissioning Plan—Design Phase.....DESIPLAN.V__

Appendix 1: Design Documentation Format—Instructions.....INSTRUCT.D__

Design Documentation Format.....D_INTENT.V__

Appendix 2: Fire & Emergency Power Response Matrix.....RESPNSM.TRX

Appendix 3: Commissioning for Indoor Air Quality Checklist.....DPLANAP3.0__

Directory: \GIDESPEC.PT3

Part III: Commissioning Guide Specifications Overview.....SPEC_OVR.V__

Section 00800: Supplementary Conditions.....00800.V__

Section 01040, Version A: Coordination.....01040A.V__

Section 01040, Version B: Coordination.....01040B.V__

Section 01300: Submittals.....01300.V__

Section 01700: Project Close-Out.....01700.V__

Section 01730: Operations and Maintenance Data.....01730.V__

Section 15010: Mechanical—General Provisions.....15010.V__

Section 15950: Automatic Controls.....15950.V__

Section 15990: Test, Adjust and Balance.....15990.V__

Section 15995: Mechanical Systems Commissioning.....15995.V__

Section 15997: Mechanical Testing Requirements.....15997.V__

Section 15998: Prefunctional Checklists—Mechanical & Electrical.....15998.V__

Directory: \PREFUNCT.PT3 ("PC" in the file name extension refers to Prefunctional Checklist. The underscore is a placeholder for the current version #.)

Air handler unit.....AHU.PC_

Air-cooled Condenser and Compressor.....AIRCNDsr.PC_

Boiler.....BOILER.PC_

Condenser Water Piping.....CDWPIPE.PC_

Chiller.....CHILLER.PC_

Sample chiller system startup documentation plan.....CHILRDOC.PC_

Chilled Water Piping.....CHWPIPE.PC_

Computer Room AC Unit.....COMPUTAC.PC_

Controls System (BAS).....CONTROLS.PC_

Cooling Tower.....COOLTWR.PC_

Exhaust Fan.....EXH_FAN.PC_

Fan Coil Unit.....FANCOILU.PC_

Heating Water Piping.....HWPIPE.PC_

Packaged Rooftop Unit	PKGUNIT.PC_
Pump (water).....	PUMP.PC_
Start-up Documentation Plan Template	STARTPLN.C06
TAB	TABPLAN.PC_
Terminal Unit	TU_PC05.XLS
Variable Frequency Drive	VFD.PC_

Directory: \GIDESPEC.PT3

Section 15999: Sample Functional Test Procedures—Mechanical	15999.V__
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Directory: \FUNCTEST.PT3 ("FT" in the file name extension refers to Functional Test. The underscore is the version #.)

Air Compressor (for smoke dampers)	AIRCOMPR.FT_
Air Handler Unit (cooling unit only)	AHU_COOL.FT_
Air-Side Economizer	ECONTEST.FT_
Cabinet Unit Heater	CABUNHTR.FT_
Chilled Water Sequence of Operations	CHILRSEQ.EXA
Chiller Functional Test.....	CHILLER.FT_
Fan Coil (heating)	HTFNCOIL.FT_
Fin Tube Radiator.....	FINTUBE.FT_
Packaged Rooftop DX Air Conditioning Unit	PKG_RTU.FT_
Packaged Boiler Control Sequences (not included in hard copy)	BOILRSEQ.00_
Packaged Boiler Functional Test	BOILERHW.FT_
Multiple Boiler System Functional Test (not included in hard copy)	BOILERSYS.FT_
Service Water Heater (Gas)	SRVC_WH.FT_
Small Service Hot Water Circulating Pumps	SMLCPUMP.FT_
Split Air Conditioning Unit	SPLIT_AC.FT_
Terminal Unit--HW Reheat Single Duct	TU_REHET.FT_
Terminal Unit--Dual Duct.....	TU_DDVAV.FT_
Terminal Unit--Dual Duct Fan (Series)	TU_DDFAN.FT_
Terminal Unit--Cooling Only VAV Single Duct.....	TU_CLG.FT_
Unit Heater	UNIT_HTR.FT_
Variable Speed Drive (fan application)	VDFAN.FT_
Variable Speed Drive (pump application)	VFDPUMP.FT_

Directory: \GIDESPEC.PT3

Section 16010: Electrical—General Provisions	16010.V__
Section 16995: Electrical Systems Commissioning	16995.V__
Section 16997: Electrical Testing Requirements	16997.V__
Section 16998: Prefunctional Checklists—Electrical	16998.V__
Section 16999: Sample Functional Test Procedures.....	16999.V__

Directory: \FUNCTEST.PT3

Emergency Power System and UPS	E-POWER.FT_
Emergency Power System and UPS (larger UPS test; not included in hard copy) ...	E-POWBIG.FT_
Exterior Lighting Controls	EXTLIGHT.FT_
Lighting Sweep Controls	SWEEP.FT_

Directory: \GIDESPEC.PT3

Section 17100: Commissioning Requirements	17100.V__
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Directory: \CONSPLAN.PT4

Part IV: Model Commissioning Plan—Construction Phase CONSPLAN.V__

Directory: \CONFORMS.PT4 (The file name extension refers to the Form ID number)

Appendix 1: Construction Phase Application Forms (25 files)

C-1: Commissioning Issues Log.....	ISSULOG.C01
C-2: Request for Documentation and Record of Submissions	DOCREQC2.XLS
C-3a: Commissioning Test or Review Approval.....	APPROVAL2.C3A
C-3b: Commissioning Prefunctional Check Submittal / Approval	PCSUBMIT.C3B
C-3c: Commissioning Transmittal.....	TRANSMIT.C3C
C-3d: Commissioning Request for Information.....	INFOREQ.C3D
C-3e: Commissioning Memorandum	MEMORAND.C3E
C-3f: Commissioning Submittal for Sequences and Test Forms	SUBFTFRM.C3F
C-4: Commissioning Progress Report	PROGREPT.C04
Training: Project Training and Orientation Procedures	TRAINPRO.CED
C-5a: Overall Staff Training and Orientation Plan.....	TRAINPLN.C5A
C-5b: Training and Orientation Agenda	TRAINAGE.C5B
C-5c: Staff Training and Orientation Record.....	TRAINREC.C5C
C-6: Commissioning Corrective Action Report.....	CORECTON.C06
C-7: Commissioning Progress Record.....	RECORDC7.XLS
C-8: Plan and Documentation Requirements for Startup and Initial Checkout	STARTPLN.C08
C-9: Detailed Commissioning Schedule (blank).....	TIMEBLC9.XLS
C-10: Detailed Commissioning Schedule (filled in).....	TIMEFC10.XLS
C-11: Commissioning Functional Testing Plan Overview	FTOVRVU.C11
C-12: Phasing of Commissioning Testing.....	PHASES.C12
C-13: Owner-Contracted Tests	OWNRTEST.C13
C-14: Facility Staff Participation in Commissioning.....	STAFFPART.C14
C-15: Functional Testing Scope Outline (example).....	SCOPEFIL.C15
C-16: Commissioning Formal Written Work Products.....	PRODUCTS.C16
C-17: Commissioning Record Notebook Format	BOOK_C17.XLS

Appendix 2: Document and Test Development Flow Charts, Submittal Maps PT4_APP2.V03

Sources

The primary sources used for the development of these commissioning plans and specifications were (listed by date):

1. Heinz, John A., Rick Casault and Phoebe Caner, *The Building Commissioning Handbook*, The Association of Higher Education Facilities Officers (APPA), 1996.
2. *Building Commissioning Guide*, Enviro-Management & Research, Inc., 1996.
3. *The HVAC Commissioning Process*, ASHRAE Guideline 1-1989R, final draft 1996.
4. Electrical Engineering Building Commissioning Specifications, Notkin Engineering/ University of Washington, 1995.
5. Caner, Phoebe, *Commissioning the Building Automation System of the Physics/Astronomy Building: A Case Study*, University of Washington, 1995.
6. *Systems Commissioning Procedures*, US Army Corp of Engineers, 1995.
7. Chamberlin, G. A. and D. M. Schwenk, *Standard HVAC Control Systems Commissioning and Quality Verification User Guide*. USACERL, FEAP-UG-FE-94/20, September 1994.

8. GSA Portland, Oregon Federal Courthouse Specifications, general commissioning section and controls testing sections, 1994.
9. Dunn, Wayne A., *C-2000 Quality Guideline, Commissioning Specifications*, Canadian Department of Energy Mines and Resources, 1994.
10. *Contractor Quality Control and Commissioning Program*, Montgomery County, Maryland, 1993.
11. General Commissioning Guide Specifications, University of Washington Facility Management Office, September 1993.
12. Kao, James Y., U.S. Department of Commerce, *HVAC Functional Inspection and Testing Guide*, March 1992
13. *Building Commissioning Guidelines*, PECO/Bonneville Power Administration, 1992.
14. Misc. specifications, guidelines and tests developed by PECO, 1990-1996.

Part I

Commissioning Requirements --Design Phase--

For Inclusion in the RFP for A/E Services

Sponsored by
US Department of Energy
Seattle Regional Support Office
800 5th Ave. Suite 3950
Seattle, WA 98104

Prepared by:
Portland Energy Conservation, Inc. (PECI)
921 SW Washington, Suite 312
Portland, OR 97205
503-248-4636, Fax 503-295-0820

Version 2.02

March 1997

Part 1

Commissioning Requirements --Design Phase--

Summary

The *Commissioning Requirements—Design Phase* are specifications relating to commissioning which the design team is required to carry out during the development of the contract documents. The requirements include a listing of the responsibilities for each member of the design team. In addition, for perspective the requirements list the responsibilities of all players during the construction phase. These requirements are intended to be included in the RFP for A/E services and for prospective commissioning agents, after GSA fills in the appropriate check boxes and blanks. The requirements include little detail, rather they point to the fully explained procedures in the *Model Commissioning Plan—Design Phase*.

In the Appendix to Part I, a sample request for proposal (RFP) for a commissioning agent is provided which will assist in engaging the services of a qualified commissioning agent for the project. This RFP was developed as a stand-alone document and is redundant of much of the material in the main part of this section.

The information in this section should be adapted for inclusion in any AIA or other standard documents used for acquiring design and consulting services. Special instructions to the specification or contract writer have been enclosed in boxes.

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Request for Proposal of A/E Services

--Design Team Commissioning Requirements--

Introduction

The General Services Administration (GSA), Region 10 is committed to the concept of commissioning all new buildings and major renovations. Commissioning is the process of achieving, verifying and documenting the performance of building systems in accordance with the design intent and the client's functional and operational needs. Commissioning starts in the design phase and extends through the construction process and into the warranty period. In brief, the commissioning process entails developing clear and complete design and operational intent documentation, verifying and documenting proper equipment and system performance, ensuring that appropriate O&M documentation is left with the building operating staff and ensuring that the building operators are sufficiently trained. Building commissioning is a team effort and requires cooperation by all parties to succeed efficiently.

1.0 General

1.1 Party Definitions

Commissioning Agent (CA) - an independent agent, not otherwise associated with the A/E team members or the Contractor, though he/she may be hired as a subcontractor to them. The CA or the architect may coordinate the commissioning during design. The CA coordinates the commissioning during construction. The CA reports directly to the GSA Project Manager during design.

Commissioning Coordinator - the party assigned to coordinate the commissioning activities during the *design* phase. This may be the CA or the architect.

Project Manager (PM) - the contracting and managing authority for GSA over the design and/or construction of the project.

Construction Manager (CM) - GSA's on-site representative or agent. The Contractor reports to the CM.

Contractor (GC) - the general contractor for the project.

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

1.2 Participation

For the Design Phase, a commissioning agent will be hired by:

- ☐ GSA directly
- ☐ the CM
- ☐ the A/E
- ☐ the GC

2.0 Responsibilities

By responding to this RFP, the A/E team acknowledges their willingness to participate in the commissioning process. The commissioning process is fully defined in the following reference documents developed by Region 10, USDOE included with this RFP: *Commissioning Guide Specifications, Model Commissioning Plan—Design Phase, Model Commissioning Plan—Construction Phase*. The GSA *Building Commissioning Guide* is also a valuable general reference guideline. For use, modification or customizing, an electronic copy of the *Guide Specifications*, as well as the other two USDOE documents, will be provided to the parties awarded the design contract.

To provide an overall perspective of the commissioning process, a *summary* of the commissioning responsibilities of *all* parties is provided below for all design and construction phases. This includes the responsibilities and tasks of the CM, PM and GC, which are not a part of the scope of this RFP. The CA responsibilities during construction and warranty are not included in the scope of this RFP. If the CA is checked below, the CA services during Design Development and Construction Documents phase are included in the scope of this RFP.

In summary, only the tasks of the following checked parties are part of the scope of A/E commissioning services for this RFP.

- ☐ Architect (Programming through Warranty)
- ☐ HVAC mechanical designer (Programming through Warranty)
- ☐ Electrical designer (Programming through Warranty)
- ☐ Commissioning agent (during Design Development and Construction Documents Phases)

2.1 All Parties

All Phases

1. Follow the *Commissioning Plan—Design Phase* included with this RFP.

2.2 Architect (of the A/E team)

Programming and Conceptual Development Phases

1. Document the tenant and GSA building criteria, needs, etc. for this building in a programming report.
2. If assigned as the design phase commissioning coordinator, make any changes necessary to the original Commissioning Plan—Design Phase provided by GSA.

Design Development

1. ☐ Coordinate the commissioning work, ☐ Commissioning agent coordinates the commissioning work.
2. Document the design intent for general building design and function as specified in the Commissioning Plan included with this RFP.

Construction Documents Phase

1. ☐ Coordinate the commissioning work, ☐ Commissioning agent coordinates the commissioning work.
2. Coordinate the development of the design intent by all design team members.

3. Document the design intent, design narrative and design parameters as specified in the Commissioning Plan included with this RFP and include this documentation in the specifications sections shown in the Commissioning Plan—Design Phase.
4. Adapt the Division 1, Sections 00800, 01040, 01300, 01700, and 01730 from Guide Commissioning Specifications into Division 1 for this project. Developing performance verification requirements to be executed by others shall not be construed to relieve the architect and design engineers of any responsibility assigned under the contractual agreement.

Construction and Acceptance Phase

1. ___ Manage the CA contract, ___ GC manages the CA contract, ___ CM or GSA manages the CA contract.
2. Perform normal submittal review, construction observation, as-built drawing preparation, O&M manual preparation, etc., as contracted.
3. Provide any design narrative documentation requested by the CA.
4. Coordinate resolution of system deficiencies identified during commissioning, according to the contract documents.
5. Prepare and submit final as-built design intent documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.

Warranty Period

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

2.3 HVAC Mechanical and Electrical Designers/Engineers (of the A/E team)

Programming and Conceptual Development Phase

—None—

Design Development Phase

1. Document design intent and general operating parameters according to the Commissioning Plan included with this RFP.

Construction Documents Phase

1. Complete the documentation of the design intent and operating parameters according to the Commissioning Plan included with this RFP and include this documentation in the specifications sections shown in the Commissioning Plan—Design Phase.
2. Adapt the Division 15 (HVAC mechanical designer) and Division 16 (electrical designer) Guide Commissioning Specifications into Division 15 and 16 for this project.

Construction and Acceptance Phase

1. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One site observation should be completed just prior to system start-up.
2. The designers shall provide the CA with additional detailed equipment and system information, as requested. 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 are not sufficient for writing detailed testing procedures.

3. Participate in the resolution of Division 15, 16 and 17 system deficiencies identified during commissioning, according to the contract documents.
4. Prepare and submit the Division 15 and 16 final as-built design intent and design and operating parameters documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
5. Provide a presentation at the first training session for the Owner's personnel.

Warranty Period

1. Participate in the resolution of respective Division 15 and 16 non-compliance and design deficiencies identified during commissioning during warranty-period commissioning.

2.4 Commissioning Agent

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 or resolving non-conformance or deficiencies, but ultimately these responsibilities reside with the general contractor 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—that is determine whether systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.

Programming and Conceptual Development Phase

—None—

Design Development Phase

1. If assigned as the design phase commissioning coordinator, make any changes necessary to the original *Commissioning Plan—Design Phase* provided by GSA.
2. ___Coordinate the commissioning work, ___Architect coordinates the commissioning work.
3. ___Perform, ___Do not perform a design review at the end of Design Development.
4. Assist design team members in developing their portions of the design intent.

Construction Documents Phase

1. ___Coordinate the commissioning work, ___Architect coordinates the commissioning work.
2. Perform a review of the drawings and specifications when 50% and 95% complete.
3. Assist, review and approve the development of the design intent and operating parameters documentation by all design team members.
4. Develop a draft project-specific commissioning plan for the construction phase, using the *Commissioning Plan—Construction Phase* model document.
5. Coordinate the development of the construction commissioning specifications.
6. Assist, review and approve the development of the construction commissioning specifications by all design team members.
7. Assist the A/E in adapting the special commissioning Division 17 Guide Commissioning Specifications into Division ___ for this project.

Construction and Acceptance Phase

According to the Contract Documents:

1. 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 consultations with all necessary parties, frequently updated timelines and schedules and technical expertise.
2. Coordinate the commissioning work and, with the GC and CM, ensure that commissioning activities are being scheduled into the master schedule.
3. Revise, as necessary, the Draft 2, Commissioning Plan—Construction Phase.
4. Plan and conduct a commissioning scoping meeting.
5. Request and review additional information required to perform commissioning tasks, including O&M materials, contractor start-up and checkout procedures.
6. Before startup, gather and review the current control sequences and interlocks and work with contractors and design engineers until sufficient clarity has been obtained, in writing, to be able to write detailed testing procedures.
7. Review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.
8. Write and distribute prefunctional tests and checklists.
9. Develop an enhanced start-up and initial systems checkout plan with Subcontractors.
10. Perform site visits, as necessary, to observe component and system installations. Attend selected planning and job-site meetings to obtain information on construction progress. Review construction meeting minutes for revisions/substitutions relating to the commissioning process. Assist in resolving any discrepancies.
11. Witness all or part of the HVAC piping test and flushing procedure, sufficient to be confident that proper procedures were followed. Document this testing and include documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
12. Witness all or part of any ductwork testing and cleaning procedures, sufficient to be confident that proper procedures were followed. Document this testing and include documentation in O&M manuals. Notify owner's project manager of any deficiencies in results or procedures.
13. Approve prefunctional tests and checklist completion by reviewing prefunctional checklist reports or by direct site observation.
14. Approve systems startup by reviewing start-up reports and by selected site observation.
15. Review testing, adjusting, and balancing (TAB) execution plan.
16. Oversee sufficient functional testing of the control system and approve it for use by TAB, before TAB is executed.
17. Approve air and water systems balancing by spot testing and by reviewing completed reports and by selected site observation.
18. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data-logger monitoring or manual functional testing. Submit to CM for review, and approval if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
20. Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
21. Maintain a master deficiency and resolution log and a separate testing record. Provide to the CM written progress reports and test results with recommended actions.

22. Witness performance testing of smoke control systems by others and all other owner contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document this testing and include in Commissioning Record in documentation in O&M manuals.
23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
24. Oversee and approve the training of the Owner's operating personnel.
25. Compile and maintain a commissioning record and building systems book(s).
26. Review and approve the preparation of the O&M manuals.
27. Provide a final commissioning report.

Warranty Period

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

2.5 Contractor and Subcontractors

No part of these specifications are to be construed to relieve the Contractor of their responsibilities under the building contract.

Programming through Construction Documents Phases

—None—

Construction and Acceptance Phase

1. The GC shall ensure that all Subcontractors (Subs) execute their commissioning responsibilities according to the contract documents in a timely fashion.
2. A representative of the subcontractor for each applicable trade shall attend a commissioning scoping meeting.
3. Subs shall provide normal cut sheets and shop drawing submittals and O&M manuals, with one copy for each piece of commissioned equipment going to the CA. Subs shall provide the CA with additional detailed equipment and system information, as requested. Subs shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation are not sufficient for writing detailed testing procedures.
4. Subs shall provide limited assistance to the CA in preparation of the specific functional performance test procedures. Subs shall review test procedures to ensure feasibility, safety and equipment protection.

5. Subs shall execute their normal system prestart-up checkout procedures without a decrease in rigor. In addition, they will complete prefunctional performance checklists and tests provided to them by the CA.
6. Subs shall perform and clearly document their normal start-up and system check-out procedures without a decrease in rigor. Subs shall provide a start-up report and a copy of the manufacturer's recommended start-up procedures to the CA. Subs shall address all A/E punch list items to date and TAB shall be completed with discrepancies and problems remedied before functional testing. Subs shall perform standard start-up testing and system operational checkouts with normal rigor. Commissioning performance verification is intended to verify proper performance, not replace the start-up testing and system debugging responsibilities of the Subs.
7. Subs shall execute functional performance testing, witnessed by the CA.
8. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, CM and A/E.
9. Prepare O&M manuals according to the contract documents.
10. Prepare red-line as-built drawings for all drawings and final as-builts for contractor-generated coordination drawings.
11. Provide training of the Owner's operating personnel.
12. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.
13. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings to the CA.
14. General contractor shall coordinate the training of owner personnel.

Warranty Period

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

2.6 Construction Manager (Owner's Rep, GSA)

Programming through Design Development Phases

—None—

Construction Documents Phase

1. Perform a general review of the drawings and specifications. Perform a constructibility review and/or perform a value engineering analysis according to their contract.

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CA, and with the GC and CA ensure that commissioning activities are being scheduled into the master schedule.
2. Review and approve the final Commissioning Plan—Construction Phase.
3. Attend a commissioning scoping meeting.
4. Perform the normal review of Contractor submittals.
5. Review and approve the functional performance test procedures submitted by the CA, prior to testing.
6. Review periodic commissioning progress and deficiency reports.
7. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.

8. Assist the Contractor in coordinating the training of owner personnel.
9. Sign-off on individual commissioning tests completed and passing. Recommend completion of the commissioning process to the Project Manager.

Note: If the CA is hired by the CM or directly by GSA, the CM tasks listed above for the commissioning process become the responsibility of the CA, as the need for oversight of the CA is essentially eliminated, except for the coordination of deficiency resolution.

Warranty Period

1. Assist the CA as necessary in the seasonal testing and deficiency corrections required by the specifications.

2.7 Project Manager (of GSA)

Programming through Design Development Phases

1. Manage the A/E contract.
2. Work with the client in determining their functional needs.
3. Perform the normal reviews of the A/E work.
4. Approve the final Commissioning Plan—Design Phase.

Construction Documents Phase

1. Manage the A/E contract.
2. As normal, represent GSA and the client in drawing and specification reviews.
3. Review and approve the design intent documentation.
4. Review and approve the commissioning specifications.
5. As normal, review the value engineering analysis and approve any changes to be incorporated.

Construction and Acceptance Phase

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

Warranty Period

1. Ensure that any seasonal testing and any deficiency issues are addressed.

Part I

APPENDIX 1

Solicitation for Commissioning Agent Services

Solicitation for Commissioning Agent Services

BACKGROUND

_____ (Owner) is seeking the services of a qualified commissioning agent/firm for a new commercial construction project. The project is a _____ gross sf, _____ story, Class _____ [type] _____ building in [city & state] _____, _____, with a project budget of \$ _____ million. The facility is expected to be comprised of _____ % office space, _____ % retail, _____ parking garage, and _____ % medical laboratory.

The project has gone through the programming phase, with a programming report available for review. The balance of design is expected to be completed by _____ and construction started by _____, with a final occupancy date of _____.

If the project is already designed, include detailed descriptions of the systems in the building that will be commissioned.

The management structure is traditional "design and spec" with full design documents and specifications to be developed by an architectural firm. The construction documents will be let out to bid and a general contractor will be hired to complete the construction. The design team will have limited construction oversight. The Owner's primary construction representative on-site will be provided by the separately contracted services of a construction management firm. The commissioning agent will report to the construction manager.

If the project is not a design and spec, describe the structure and the oversight and lines of responsibility for the A/E, commissioning agent and owner's representative.

If you are providing the CA with more detailed design phase commissioning requirements, a design phase model plan, sample commissioning construction specifications and a model construction phase commissioning plan for reference, you can delete out the redundant areas of this RFP.

SCOPE OF WORK

The Owner is committed to commissioning this facility to ensure that all systems are complete and functioning properly upon occupancy and that facility staff have adequate system documentation and training. Commissioning consists of systematically documenting that specified components and systems have been installed and started up properly, and then functionally tested to verify and document proper operation through all modes and conditions. In

addition, owner-personnel training will be verified and final project operations and maintenance (O&M) documents will be reviewed for completeness.

The following is a summary of the commissioning process which the Owner intends to have implemented on this project. The proposer is free to suggest changes and improvements to this process. However, for this proposal the following process will be assumed.

Commissioning Process During Design

A summary of the commissioning process during design is:

1. A design phase commissioning plan is developed by the commissioning agent (CA).
2. The design team members perform their normal functions in addition to the commissioning related tasks of documenting the design intent.
3. The CA performs a focused review of design development.
4. The CA develops the draft commissioning plan for the construction phase.
5. The CA develops commissioning specifications for the construction documents, with review by the design team, for inclusion in their construction specifications.
6. The design team develops in-depth design documentation, including design intent, basis of design and full sequences of operation for inclusion in the construction documents.
7. The CA performs a design review at 50% and 95% completion of the drawings and specifications.
8. The CA updates the original draft of the commissioning plan for the construction phase.

Commissioning Process During Construction and Warranty

A summary of the commissioning process that the Owner will follow during construction is:

1. A commissioning plan is developed by the commissioning agent.
2. A scoping meeting is conducted by the CA where the commissioning process is reviewed with the commissioning team members.
3. 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.
4. Equipment documentation is submitted to the CA during normal submittals, including detailed start-up procedures.
5. The CA works with the Subcontractors (Subs) in developing start-up plans and start-up documentation formats, including providing to the Subs prefunctional checklists to be completed during the startup process.
6. 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.
7. The Subs, under their own direction, 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 may include the CA witnessing startup of selected equipment.
8. The CA develops specific equipment and system functional performance test procedures. The Subs review the procedures.
9. The procedures are executed by the Subs, under the direction of, and documented by the CA.
10. Items of non-compliance are corrected at the Subs' expense and the system retested.
11. The CA reviews the O&M documentation for completeness.

12. Commissioning is completed before Substantial Completion.
13. The CA reviews, pre-approves and coordinates the training provided by the Subs and verifies that it was completed.
14. Deferred and seasonal testing and performance evaluation is conducted, as specified or required.

Commissioning Agent Responsibilities

The proposer is free to suggest changes and improvements to following task list. However, for this proposal the following tasks will be assumed.

The commissioning agent/firm (CA) will have the following responsibilities:

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 or resolving non-conformance or deficiencies, but ultimately that responsibility resides with the general contractor 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—that is determine whether systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.

Programming and Conceptual Development Phase

—None—

Schematic Design and Design Development Phase

1. Coordinate the commissioning work during design
2. Develop a design-phase commissioning plan, using the draft or “boilerplate” version provided by the Owner or other approved models.
3. Perform a focused design review at the end of Design Development, as described in Exhibit 1.
4. Assist design team members in developing their portions of the design intent. Approve their submissions.

Construction Documents Phase

1. Coordinate the commissioning work during this phase.
2. Perform a focused review of the drawings and specifications when 50% and 95% complete, as described in Exhibit 2.
3. Assist, review and approve the development of the design intent and operating parameters documentation by all design team members.
4. Develop a draft project-specific commissioning plan for the construction phase, using the “boilerplate” version provided by the owner or other approved models.
5. Develop full commissioning specifications for all commissioned equipment listed below using one or more of the following documents as a guide for content, rigor and format: 1) *Model Commissioning Plan and Guide Specifications*, USDOE/FEMP; Portland Energy Conservation, Inc. (PECI). Available in electronic and hard copy form from National Technical Information Service (NTIS) at 1-800-553-6847 and on the internet through PECO,

<http://www.teleport.com/~peci>. 2) *Facility Design Information Manual*, Engineering Services, University of Washington. Available over the internet at <http://weber.u.washington.edu/~fsesweb>, under Vol. 2 Division 17 Commissioning. 3) *The HVAC Commissioning Process*, ASHRAE Guideline 1-1989R. Available from ASHRAE at 404-636-8400.

The commissioning specification will include a detailed description of the responsibilities of all parties included in the commissioning process; details of the commissioning process; reporting and documentation requirements, including formats; deficiency resolution; prefunctional checklist and startup requirements; the functional testing process; specific functional test requirements, including testing conditions and acceptance criteria for each piece of equipment being commissioned.

6. Have the commissioning specifications approved by the A/E team and included in the A/E construction specifications.

Construction and Acceptance Phase

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

15. Review testing, adjusting and balancing (TAB) execution plan.
16. Oversee sufficient functional testing of the control system and approve it to be used for TAB, before TAB is executed.
17. Approve air and water systems balancing by spot testing and by reviewing completed reports and by selected site observation.
18. With necessary assistance and review from installing contractors, write the functional performance test procedures for equipment and systems. This may include energy management control system trending, stand-alone data-logger monitoring or manual functional testing. Submit to CM for review, and approval if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
20. Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
21. Maintain a master deficiency and resolution log and a separate testing record. Provide to the CM written progress reports and test results with recommended actions.
22. Witness performance testing of smoke control systems by others and all other owner contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document and include in Commissioning Record in O&M manuals.
23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
24. Oversee and approve the training of the Owner's operating personnel.
25. Compile and maintain a commissioning record and building systems book(s).
26. Review and approve the preparation of the O&M manuals.
27. Provide a final commissioning report.

Select the warranty period services desired below.

Warranty Period

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

Assumptions

It is assumed that the A/E will provide adequate written design intent, basis of design and full sequences of operation for all equipment and systems for the O&M manuals and for the commissioning agent to use in writing functional tests. It is also assumed that the contractors will execute the functional testing of equipment, coordinated and documented by the commissioning agent, using forms provided by the commissioning agent.

Systems To Be Commissioned

The following systems, including all components and controls, will be commissioned:

Delete and add systems as desired.

1. Central building automation systems, including linkages to remote monitoring and control sites (this excludes any security-related control systems or interlocks).
2. All equipment of the heating, ventilating and air conditioning systems.
3. Medical laboratory clean room hoods and pressurization
4. Refrigeration systems
5. Life safety systems (fire alarm, egress pressurization, fire protection)
6. Domestic and process water pumping systems
7. Emergency power and uninterruptible power supply (UPS) systems
8. Lighting control systems
9. Communication and paging systems

The following outlines the level of effort expected for each commissioned system:

The CA shall review the design documentation (design intent, basis of design and sequences of operation) for completeness. The CA shall develop prefunctional checklists for the installing contractors to include in their startup and initial checkout. The CA shall develop detailed written test procedures for guiding and documenting performance during functional testing.

The functional testing shall include operating the system and components through each of the written sequences of operation and other significant modes and sequences, including startup, shutdown, unoccupied mode, manual mode, staging, miscellaneous alarms, power failure, security alarm when impacted and interlocks with other systems or equipment. Sensors and actuators shall be calibrated during prefunctional checklisting by the installing contractors and spot checked by the commissioning agent during functional testing.

Tests on respective HVAC equipment shall be executed during both the heating and cooling season. However, some overwriting of control values to simulate conditions may be allowed, if used judiciously. The central plant shall have its efficiency bench-marked for later use by operations staff. Functional testing shall be done using conventional manual methods, control system trend logs or stand-alone dataloggers, to provide a high level of confidence in proper system function, as deemed appropriate by the commissioning agent and the Owner.

DESIRED QUALIFICATIONS

It is desired that the person designated as the site commissioning agent satisfy as many of the following requirements as possible:

1. Have acted as the principal commissioning agent for at least three projects over 100,000 sf.

Increase or reduce the size of required project experience, depending on your project.

2. Have extensive experience in the operation and troubleshooting of HVAC systems, energy management control systems and lighting controls systems. Extensive field experience is required. A minimum of five full years in this type of work is required.
3. Knowledgeable in building operation and maintenance and O&M training.
4. Knowledgeable in test and balance of both air and water systems.
5. Experienced in energy-efficient equipment design and control strategy optimization.
6. Direct experience in monitoring and analyzing system operation using energy management control system trending and stand-alone datalogging equipment.
7. Excellent verbal and writing communication skills. Highly organized and able to work with both management and trade contractors.
8. Experienced in writing commissioning specifications.
9. A bachelors degree in Mechanical Engineering is strongly preferred and P.E. certification is desired, however, other technical training and past commissioning and field experience will be considered.
10. The majority of the required expertise for this project must be part of the skill and experience set of the prime firm making the proposal. A member of that firm will be the designated Commissioning Agent. The Commissioning Agent must be fully qualified to commission most of the above listed systems. If the Commissioning Agent or prime firm does not have sufficient skills to commission a specific system, the prime firm shall subcontract with a qualified party to do so. That party's qualifications shall be included and clearly designated in the response to this RFP.
11. The Commissioning Agent will be an independent contractor and not an employee or subcontractor of the General Contractor or any other subcontractor on this project, including the A/E.

If the project is large (>200,000 sf or so), include the following language and other language as appropriate. Specify project sizes, etc.

It is desired that the prime commissioning firm have a designated project manager with the following qualifications. This person may also be the designated primary site commissioning agent.

1. Experienced in the design process of large projects > _____ sf.
2. Experienced in working with the construction management and process protocols of large buildings and projects.
3. Experienced in managing multi-year projects.

INSTRUCTIONS TO PROPOSERS

A proposer must propose to execute all phases of the commissioning in a single proposal. However, the proposer will provide separate prices for the design and construction/warranty phases shall be provided.

The proposal shall be limited to 15 single-sided pages, including graphics. A letter of introduction, section dividers, detailed resumes and the sample work products of item five below are not included in this limit.

The proposal must be signed by an officer of your firm with the authority to commit the firm.

1. Fill out the attached Commissioning Firm Experience form, including the Project Experience Listing form (Exhibits 4 and 5).
2. List the key individual who will be the commissioning agent for this contract and describe his or her relevant qualifications and experience. This information is required in addition to any detailed resumes the proposer submits. The contract will require that this individual be committed to the project for its duration.
3. List the relevant experience of project management, supporting staff and subconsultants, including detailed resumes, with the fraction of expected hours for each. Project management, supporting staff and subconsultants shall provide less than ____% of the total time on the project.

The above fraction should range from 20 to 50%. Larger, more complex projects and projects with a variety of primary system types will have fractions in the upper range.

4. Provide project and professional references and experience for three to five commissioning projects for which the proposer was the principal commissioning agent in the last three years. Include a description of the project, including square footage and systems commissioned. Identify when the proposer came into the project. *Describe* the involvement of each individual on the proposer's team in the projects for the following areas: systems *and components* commissioned, specification writing, design review, commissioning plan development, functional testing procedures and forms, coordinating and overseeing functional testing, actually performing the functional testing (hands-on), troubleshooting involvement, project management, O&M manual reviews and O&M training. Provide this data on the attached Commissioning Project Experience Listing form. For each project, attach a sheet that includes the name and telephone number of the owner's project manager, construction manager, facility administrator of the building, the mechanical designer, the controls contractor site project manager, the mechanical contractor and electrical contractor.
5. Describe any experience of the proposer's team in the following areas. List the each party's involvement.
 - a) traditional test and balance;
 - b) commissioning laboratories;
 - c) O&M experience;
 - d) energy-efficient equipment design and control strategy optimization;
 - e) life cycle costing; and
 - f) experience in environmental sustainable design.
 - g) project and construction management

Delete items in the above list for areas that you do not want the commissioning agent to provide specific task work.

6. Describe your proposed approach to managing the project expertly and efficiently, including your team participation. Describe what approach you will take to integrate the commissioning into the normal design and construction process in order to minimize potential time delays. Describe what you will do to foster teamwork and cooperation from contractors and designers and what you will do to minimize adversarial relationships. Describe how you intend to determine the appropriate level of commissioning effort for the various systems and equipment. Describe how your work will facilitate the use of your product as a prototype

which may be subsequently used by the Owner in future projects, including access to the electronic versions of all documents and forms.

7. As an attachment, provide the following work products that members of the proposer's team wrote. List the team member who actually wrote the document and the projects on which they were used. Work from the designated commissioning agent is highly preferred.
 - a) commissioning plan;
 - b) commissioning specifications; and
 - c) an actual functional test procedure form that was executed.
8. Provide both an estimated total fee to accomplish the work and an hourly rate for each team member if the project is set up on a time-and-materials basis. The Owner will negotiate with the selected proposer and may contract on a fixed fee or time and materials basis.

SELECTION CRITERIA

Scale the weights below as desired.

The submitted proposals will be reviewed and ranked according to the following (items from the above numbered list):

1. & 2. Key individual experience	20 points
3. Staff and subconsultant experience	10 points
4. Similar project experience	15 points
5. Team experience in related skill areas	15 points
6. Management approach	20 points
7. Work examples	10 points
8. Fee proposal	<u>10 points</u>
	100 points

Reference checks will not be scored individually, but may be used to supplement all categories. The Owner reserves the right to eliminate or change the weight of extremely high or extremely low fee proposals.

SUBMISSION AND SELECTION

Consultants will submit _____ () copies of the written proposal, to be received in the Owner's office at [address _____] by [date and time _____]. Late proposals will not be accepted.

Review and selection process

Requirement of personal interview for finalists.....

PROTESTS

Wording as required.....

LIMITATIONS AND PROVISIONS

Wording on right to reject, to seek clarifications, to negotiate a final contract. Cost of proposal preparation not reimbursable. Primary contact for questions. Other necessary legal language, etc.....

Date due, where to submit, number of copies, etc.

MINIMUM REQUIREMENTS FOR CONTRACT EXECUTION

General Conditions.

Misc. as required.....

Insurance

The commissioning firm shall obtain, at the firm's expense, and keep in effect during the term of the project, liability insurance covering with the following limits etc.

Change in Personnel

If the commissioning firm's personnel or subconsultants change for this project, the Owner must review and approve the replacement personnel, in advance. The replacement personnel shall have, at minimum, equivalent qualifications as the original personnel.

.....List other legal requirements as required

Exhibit 1

Check the areas for which you want the commissioning firm to provide input.

FOCUSED DESIGN DEVELOPMENT REVIEW ELEMENTS

The following checked areas will be reviewed by the commissioning agent.

Design Area	Review Description
☐ <i>Commissioning facilitation</i>	Input regarding making the building easier to commission (see Exhibit 3)
☐ <i>Energy Efficiency</i>	General efficiency of building shell, building layout, HVAC system types, lighting system type, etc.
☐ <i>Operations and Maintenance (O&M).</i>	How building O&M can be made easier (accessibility and system control, etc.)
☐ <i>Indoor Environmental Quality (IEQ)</i>	How thermal, visual, acoustical comfort or air quality can be improved
☐ <i>Functionality for Tenants</i>	How the design can be changed to improve functionality for the occupants
☐ <i>Environmental Sustainability</i>	How the building materials and systems and landscaping can create less of an impact on the environment
☐ <i>Life Cycle Costs</i>	Life cycle assessment of options relative to energy efficiency, O&M, IEQ or functionality

Exhibit 2

Check the areas for which you want the commissioning firm to provide input.

FOCUSED 50% AND 95% DESIGN REVIEW ELEMENTS

The commissioning agent will perform a review at 50% and 95% design construction documents completion comprised of the following checked areas:

Design Area	Review Description
☐ <i>Commissioning facilitation</i>	Input regarding making the building easier to commission (see Exhibit 3).
☐ <i>Component energy efficiency</i>	Review for adequacy of the efficiency of bldg. shell components, HVAC systems and lighting systems.
☐ <i>Control system & control strategies</i>	Review ☐ HVAC, ☐ lighting, ☐ fire control, ☐ emergency power, ☐ security control system, strategies and sequences of operation for adequacy and efficiency.
☐ <i>Operations and maintenance</i>	Review for effects of specified systems and layout toward facilitating O&M (equipment accessibility, system control, etc.).
☐ <i>Indoor environmental quality</i>	Review to ensure that systems relating to ☐ thermal, ☐ visual, ☐ acoustical, ☐ air quality comfort, ☐ air distribution are in accordance with the design intent.
☐ <i>Environmental sustainability</i>	Review to ensure that the ☐ building materials, ☐ landscaping, ☐ use of water resources, ☐ waste management are in accordance with the design intent.
☐ <i>Functionality for occupants</i>	Review to ensure that the design meets the functionality needs of the occupants.
☐ <i>Life cycle costs</i>	Perform a ☐ qualitative, ☐ quantitative life cycle assessment of the primary competing systems relative to ☐ energy efficiency, ☐ O&M, ☐ IEQ, ☐ functionality.
☐ <i>O&M documentation</i>	Verify that building O&M plan and documentation requirements specified are adequate
☐ <i>Training</i>	Verify that operator training requirements specified are adequate.
☐ <i>Commissioning specifications</i>	Verify that bid documents adequately specify building commissioning and that there are adequate monitoring and control points specified to facilitate commissioning and O&M (trending capabilities, test ports, control points, gages and thermometers).

Exhibit 3

COMMISSIONING FACILITATION REVIEW

One of the primary tasks for the commissioning agent is reviewing the design documents to facilitate commissioning during construction. The construction-phase commissioning process can be made easier and more effective if certain features are included in the design. The added up-front costs for most of these features can be justified because they reduce the cost of commissioning, allow for a better commissioning job and reduce the O&M costs for the building. Below is a list of some of these features. Not all are addressed in detail in the design development review. However, they should be brought to the attention of the A/E at this time, so that they can be incorporated during the construction documents phase. The review is not expected to be limited to only those issues listed below.

- Clear and rigorous design documentation, including detailed and complete sequences of operation.
- An HVAC fire and emergency power response matrix that lists all equipment and components (air handlers, dampers, valves, etc.) with their status and action during a fire alarm and under emergency power.
- Access for reading gages, entering doors and panels, observing and replacing filters, coils, etc.
- Required isolation valves, dampers, interlocks, piping, etc. to allow for manual overrides, simulating failures, seasons and other testing conditions.
- Sufficient monitoring points in the building automation system (BAS), even beyond that necessary to control the systems, to facilitate performance verification and O&M.
- Adequate trending and reporting features in the BAS.
- Pressure and temperature (P/T) plugs close to controlling sensors for verifying their calibration.
- Pressure gages, thermometers and flow meters in strategic areas to facilitate verifying system performance and ongoing O&M.
- Pressure and temperature (P/T) plugs at less critical areas or on smaller equipment where gages and thermometers would be over-kill.
- Specification of the location and criteria for the VAV duct static pressure sensor and chilled water differential pressure sensor.
- Adequate balancing valves, flow metering and control stations and control system functions to facilitate and verify reliable test and balance.
- Uniform inlet connection requirements to VAV terminal boxes.
- Clear and complete commissioning specifications for the construction phase.
- Complete O&M documentation requirements in the specifications.
- Complete training requirements in the specifications.
- Review entire document and building information management plan from design through construction and turnover to ensure adequacy and compliance with the owner's program.

Exhibit 4

COMMISSIONING FIRM EXPERIENCE

Company Name		Contact Person	Title
Address	City	State/Prov	Zip/Postal Code
Telephone	Fax	E-Mail	

Description of Business

Commissioning Activities

Percentage of overall business devoted to commissioning services _____ %
 How long has the firm offered commissioning services _____ years
 Average number of commissioning projects performed each year: _____ projects

Systems (technologies) for which firm has provided commissioning services (check all that apply) ■

☐ Pkg or split HVAC	☐ Daylighting	☐ Commercial refrigeration
☐ Chiller system	☐ Electrical, general	☐ Telecommunications
☐ Boiler system	☐ Electrical, emerg. power	☐ Thermal Energy Storage
☐ Energy Mgmt. System	☐ Envelope	☐ Labs & Clean Rooms
☐ Variable Freq. Drives	☐ Fire/Life Safety	☐ _____
☐ Lighting Controls	☐ Plumbing	

Number of registered professional engineers on staff who have directed commissioning projects: _____

The firm has provided commissioning services in the following: (check all that apply) ■

Building Sector	New Construction Major Renovation	Existing Building (Building Tune-up)	Equipment Replacement
Office	☐	☐	☐
Retail	☐	☐	☐
Grocery	☐	☐	☐
Hospitals	☐	☐	☐
Laboratories	☐	☐	☐
Schools	☐	☐	☐
Universities	☐	☐	☐
Federal, state, local gov't	☐	☐	☐
Industrial / Manufacturing	☐	☐	☐
Special purpose—prisons, museums, libraries, etc.	☐	☐	☐

Exhibit 5

Design Review: Reviewed design and provided comment during design stage

Cx Plan: Wrote the commissioning plan

Specifications: Wrote commissioning specifications for construction team

Fund. T. Plans: Wrote functional test procedures

Witnessed FT: Witnessed and documented functional tests

Hands-On Tests: Performed functional tests (hands-on)

Data/trendlogs: Used data-loggers or EMS trend logs for testing
Training: Developed or approved staff training
Review O&Ms: Reviewed completed O&M manuals
CA in Firm: Reviewed commissioning agent staff
Supervised CA: Supervised commissioning agent subcontractant to firm
Worked w/ CA: Worked with a commissioning agent hired by others

CA_EXPERXLS, 1

Part II

Model Commissioning Plan

--Design Phase--

Sponsored by
US Department of Energy
Seattle Regional Support Office
800 5th Ave. Suite 3950
Seattle, WA 98104

Prepared by:
Portland Energy Conservation, Inc. (PECI)
921 SW Washington, Suite 312
Portland, OR 97205
503-248-4636, Fax 503-295-0820

Version 2.02

March 1997

Part II

Model Commissioning Plan --Design Phase--

Summary

The *Model Commissioning Plan—Design Phase* guides the commissioning activities during the design phase. It provides details of responsibilities called out in Part I, *Commissioning Requirements—Design Phase* for the architect, design engineers, commissioning agent, construction and project managers. The plan describes the duties of the A/E team and commissioning agent in developing the site-specific commissioning specifications and for developing the first two drafts of the *Commissioning Plan—Construction Phase*.

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Instructions for the Owner Filling Out the Model Commissioning Plan—Design Phase

Using the Plan with the RFP

The *Model Commissioning Plan—Design Phase* should be used for obtaining design proposals which will include commissioning and to guide the commissioning work throughout the design process. The *Design Phase Commissioning Plan* is referred to as the *Model plan* when it is not yet filled out. Refer to the Overview of the entire *Model Commissioning Plan and Guide Specifications* for further instructions about using the plan during the design process.

Instructions for Filling Out the Model Plan

With the following directions, the owner's staff can confidently fill out the Model Plan and RFP Requirements. The awarded commissioning agent or architect will later revise the plan as necessary. The Model Plan is intended as a true "boilerplate" for most projects and can be filled out by hand without any attachments. For projects with unusual contracting arrangements, editing the Model Plan may be necessary, and is provided on electronic media.

First fill out Section 2, Building Information, to provide the expected magnitude of the project in gross terms. Section 3 will not be filled out until the design contract is awarded.

Next, skip to Section 5, Commissioning Scope of Work. Here, the first decision to be made is to decide which systems will be commissioned. At a minimum, the HVAC, HVAC control system and lighting controls should be commissioned. Consulting with other project managers, your own experience and budget considerations will help you decide on the others.

Next, under Task 1 of Section 5, Overall Coordination, decide whether the architect or the commissioning agent will coordinate the commissioning during design. The commissioning agent is generally a good choice to start with, but in some design teams the architect may be the better party, especially where the architect is more than just casually interested in commissioning, or where, with the commissioning agent as the coordinator, not enough support will be given to the commissioning agent from the other members of the team. Your decision can always be changed after the award of the contract.

Generally the formal commissioning should start at the beginning of the Design Development Phase. For smaller, less complex projects, the commissioning effort could wait until the beginning of the Construction Documents Phase.

Next, under Task 3 of Section 5, Design Development Review, decide how much, if any, the commissioning agent will review the design at the end of Design Development. This is highly recommended. The number of design areas the commissioning agent reviews is dependent on the commissioning agent's skills and the emphasis and interest by the owner and the tenants in particular areas. At a minimum, the commissioning agent should review the energy-efficiency, operations and maintenance and the indoor environmental quality issues. Desired areas for review should be checked in Table 5-1.

Under Task 4 of Section 5, Develop Design Documentation, decide for which systems the designers will provide documented detailed design intent and operational parameters. Generally, all of the listed areas are highly recommended. Also under Task 4, who will coordinate the development of the design intent documentation—the commissioning agent or the architect—must be determined. Either party should work well. The desired areas for documentation should be checked.

Task 5 of Section 5, Develop Construction Phase Commissioning Plan, requires no input, unless there are areas in the as-is *Model Commissioning Plan—Construction Phase* (Part IV) that the owner does not want to include. If so, the exclusions should be footnoted under this task.

Task 6 of Section 5, Develop Commissioning Specifications, requires no input at this time, unless there are large significant areas of the *Guide Specifications* (Part III) that the owner wants changed or clarified now, rather than during the normal adaptation process. If so, these exclusions or clarifications should be given under Task 6. It is noted that the *Guide Specifications* are not intended to be totally applicable to the project at hand and that the job of the design team is to adapt them. Thus, most or all of the changes needed will be made during the design process with guidance and approval of the owner.

Task 7 of Section 5, Conduct a Final Design Review, requires similar input as Task 3, using Table 5-3.

The Commissioning Schedule in Section 6 is fairly universal and will generally require no input. The only change that might be needed is if the commissioning starts later than the beginning of Design Development.

Finally, go to Table 4-1 in Section 4. This is a one-page view of the commissioning roles and responsibilities of the design team. In Table 4-1, there are two areas requiring input: 1) Who the overall commissioning coordinator during *design* will be, and 2) Who the lead on Task 4 will be. Check the appropriate party for these tasks and verify the other checks.

Commissioning Plan—Design Phase

Project: _____

GSA Contact: _____

Date: _____

1. Overview of Commissioning During Design

Commissioning (Cx) is a systematic process of ensuring that all building systems perform interactively according to the design intent and the owner's operational needs. This is achieved by beginning at the design phase with documented design and operating intent and continuing through construction and acceptance with actual verification of performance.

Commissioning during design is intended to achieve the following specific objectives:

- Provide commissioning focused design review.
- Ensure that the design and operational intent are clearly documented.
- Ensure that commissioning for the construction phase is adequately reflected in the bid documents.

The commissioning process during design is illustrated in Figure 1-1.

For reference, a brief description of the GSA design phases follows. Refer to the *Part I, Commissioning Requirements—Design Phase* for a listing of party definitions.

Programming—Design team and GSA Project Manager meet with representatives of the occupying agency or client and determine the square footage and occupancy requirements of the building.

Conceptual Design Phase—Architect develops block diagrams, building sizing, rough space planning and sketches of exterior types. Multiple choices are provided. Mechanical and electrical designers generally have no input in this phase.

Design Development Phase—Additional detail is applied to the block diagrams and layouts. Interior and exterior features and finishes and *general* HVAC system types are determined and a rough floor plan is approved. Value engineering, if any, is completed.

Construction Documents Phase—Drawings are completed. Specifications are completed, generally using the GSA Master Spec. Bid documents are prepared.

2. Building Information

Project Name: _____

Location: _____

Building Type (office, court, etc.): _____

Square Footage: _____ Expected number of stories: _____

Agency: _____ Tenants: _____

Design Period: _____ Const. Period: _____

Figure 1-1. Commissioning During Design

3. Design Project Team Data

GSA Project Manager	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
Commissioning Agent (CA)	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
Architect	Names: Company:	Voice Ofc: Fax: Address:	Cell: Email:
HVAC Mechanical Designer	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
Electrical Designer	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
Construction Manager	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
Tenant Representative	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:
	Name: Company:	Voice Ofc: Fax: Address:	Cell: Email:

4. Responsibilities

Tasks

A list of the responsibilities and tasks for each party of the design team are presented in Table 4-1. The member assigned as the lead for a given task is shown. The lead will coordinate the completion of the task. Under each task listing are subtasks with an “X” marked by the participating team members. The tenant representative(s) are considered members of the design team and will contribute in their normal fashion. They have no new role in the commissioning effort and so are not listed in the table.

Scope

Section 5 provides additional detail regarding scope of the tasks.

Reporting

Members completing subtasks report to the lead for that task, per Table 4-1. The task lead reports to the Coordinator lead (the lead in Task 1).

Table 4-1. Commissioning Roles and Responsibilities During Design

Task	Design Phase Commissioning Responsibilities and Tasks	Parties Involved					
		Commissioning Agent	Architect	Mechanical Designer (HVAC)	Electrical Designer	GSA Project Manager	GSA Const. Manager
1 Overall coordination of the Cx work during Design	<i>Lead--></i>						
a. Plan and schedule meetings		X	X			X	
b. See that all tasks are carried out		X	X			X	
c.							
2 Finalize the Cx plan for Design Phase	<i>Lead--></i>	X					
a. Edit the original Cx Plan as necessary		X					
b. Review and comment on Cx plan			X			X	
c.							
3 Perform design development review [1]	<i>Lead--></i>	X					
a. After completion of Design Development, review design concepts of the areas checked in Table 5-1.		X	--	--	--	--	
b.							
4 Develop design & operating intent documentation	<i>Lead--></i>						
a. Provide design intent format and assistance		X					
b. Write design intent for systems checked under Task 4 in Section 5.			X	X	X	X	
c. Review and approve design intent for clarity and completeness		X				X	
d.							
5 Develop draft Cx plan for Construction Phase	<i>Lead--></i>	X					
a. Adapt and edit the Model Cx Plan--Const. Phase, Draft 1 and 2		X					
b. Review Cx plan						X	X
c.							
6 Develop Cx specifications for construction	<i>Lead--></i>	X					
a. Assist in, review & approve all sections		X					X
b. Adapt Cx guide specs & include in Division 1		X	X				
c. Adapt Cx guide specs & include in Division 15 (HVAC)				X			
d. Adapt Cx guide specs & include in Division 16 (electrical)					X		
e. Adapt Cx guide specs in special Cx Division		X					
f. Adapt Cx guide specs & include in Division							
g.							
7 Review final drawings and specifications [1]	<i>Lead--></i>	X					
a. Review full drawings & specifications at ~50% & ~95% complete to ensure that the design intent is met (see Table 5-3).		X	--	--	--	--	--

[1] This does not preclude the normal reviews by all parties, denoted by a dash —, but is intended to show the added review by the commissioning agent.

5. Commissioning Scope of Work

The following checked systems will be commissioned in this project:

- ☒ HVAC system (virtually all equipment)
- ☒ HVAC system (primary equipment only)

- ☐ HVAC energy management control system
- ☐ Indoor air quality (moderate level of effort)
- ☐ Indoor air quality (rigorous level of effort)
- ☐ Automatic Lighting controls
- ☐ Electrical system power quality, grounding, etc.
- ☐ Emergency power system
- ☐ Communications system, e.g., _____
- ☐ Security system
- ☐ Fire/smoke alarm and control system
- ☐ Plumbing systems
- ☐ Telecommunications and data systems
- ☐ _____
- ☐ _____

The following tasks comprise the commissioning work during design:

1. Coordinate the commissioning activities
2. Finalize design phase commissioning plan
3. Perform a review of Design Development
4. Develop design intent documentation
5. Develop the draft commissioning plan for the construction phase
6. Develop commissioning specifications for the construction bid documents
7. Perform a final review of the drawings and specifications

A listing of these tasks with the parties involved with them is included in Table 4-1. Each of the tasks in Table 4-1 will be executed unless specifically noted otherwise.

5.1 Task 1. Coordination of Commissioning During Design

The commissioning agent, architect will be the coordinator of the commissioning activities during design, per the designations in Table 4-1. The beginning of this task consists of holding a kick-off meeting with the design team at the beginning of Conceptual Design Phase, Design Development Phase, Construction Documents Phase. This meeting is held after the Cx Plan has been finalized (Task 2). The meeting includes reviewing the process and outlining each party's responsibilities.

The coordinator will ensure that commissioning issues are part of design team meeting agendas and will ensure that the Leads for each task understand their responsibilities and execute them. The coordinator makes any necessary changes to the design phase Commissioning Plan provided by GSA to the A/E team during the proposal process (Task 2). The coordinator reports to the architect and to the GSA Project Manager.

5.2 Task 2. Design Phase Commissioning Plan

The commissioning coordinator for the design phase (Task 1) makes any necessary clarifications and changes to the original design phase Commissioning Plan provided by the Owner at the RFP stage and submits it to the architect and GSA Project Manager for approval. This final plan guides the commissioning work during design. Necessary adjustments to the design team's fees relative to Commissioning Plan changes are negotiated. All design team members receive a copy of the plan from the coordinator.

5.3 Task 3. Design Development Review

At the end of Design Development, the commissioning agent *reviews*, *does not review* the design along with the other design team members. If the commissioning agent does not perform this review, the rest of this section does not apply, otherwise:

The commissioning agent compares the design with the interests and needs of GSA as identified in the programming report of the Programming and Conceptual Design Phases. The commissioning agent also compares the proposed design against the GSA design guide (PBS-PQ100.1, *Facilities Standards for the Public Buildings Service*) for the design areas checked below. The commissioning agent also identifies any improvements that can be made in areas checked below. Though the commissioning agent may review the areas checked below, they are not *responsible* for design concept, design criteria or compliance with codes.

Table 5-1. Commissioning Agent Design Development Review

Design Area	Review Description
<u> </u> Commissioning facilitation	Input regarding making the building easier to commission (see Commissioning Facilitation under Section 5.7)
<u> </u> Energy Efficiency	General efficiency of building shell, building layout, HVAC system types, lighting system type, etc.
<u> </u> Operation and Maintenance (O&M).	How building O&M can be made easier (accessibility and system control, etc.)
<u> </u> Indoor Environmental Quality (IEQ)	How thermal, visual, acoustical comfort or air quality ¹ can be improved
<u> </u> Functionality for Tenants	How the design can be changed to improve functionality for the occupants
<u> </u> Environmental Sustainability	How the building materials and systems and landscaping can create less of an impact on the environment
<u> </u> Life Cycle Costs	Life cycle assessment of options relative to energy efficiency, O&M, IEQ or functionality

¹ To perform this review, the commissioning agent, in consultation with the owner to establish scope, shall use the checklists provided in Appendix 3. Indoor air quality (IAQ) commissioning does not ensure that indoor air quality will be adequate or without deficiency at building turnover or during occupancy, unless the owner has specifically specified that actual air quality testing is performed. Commissioning indoor air quality entails performing tasks that minimize the potential for IAQ problems, but it does not eliminate their possibility.

This review is documented in writing and submitted to the design phase commissioning coordinator and forwarded to the architect and GSA Project Manager. The architect distributes the comments to the design team members. The team members respond to the architect who provides a written response to the commissioning agent and to the GSA Project Manager describing the team's response and any changes or considerations made in the design.

5.4 Task 4. Design Intent and Basis of Design Documentation

Specifically identifying and developing the design intent and basis of design provides each party involved, at each respective stage, an understanding of the building systems. This allows team members to perform their respective responsibilities regarding the design, construction or operation of the building.

The design documentation differs from traditional specifications in that it provides a more narrative description of the system or issue and “frames” the issue or building component with clear and useful background information. However, design documentation often includes parts of specifications. In general, specifications detail what is to be done on a component level, while design documentation explains why something is done and, in general terms, how design and operating objectives will be accomplished. Sections of the design documentation can look like specifications, especially where tasks depart from conventional practice, e.g., energy-efficient design and construction.

Design documentation includes the salient information from the programming report, the conceptual design phase and from the design and construction process necessary to guide the design, verify compliance during construction and aid building operations. Design documentation consists of two dynamic components: design intent and the basis of design.

Design Intent

The design intent is 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. The design intent narrative should cover the following, for each system, major component, facility and area:

- General system description
- Objectives and functional use of the system, equipment or facility
- General quality of materials and construction
- Occupancy requirements
- Indoor environmental quality, IEQ (space temperature, relative humidity, indoor air quality, noise level, illumination level, etc.)
- Performance criteria (general efficiency, energy and tolerances of the IEQ objectives, etc.)
- Budget considerations and limitations
- Restrictions and limitations of system or facility

Many of the above topics may not be necessary for smaller components, such as VAV terminal units.

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. The following should be included in the basis of design for major equipment:

- Specific description of systems, components and methods for achieving the design intent objectives. (For example, for a rooftop air conditioning unit include: why this system was chosen above others, details of size, efficiencies, areas served, capacity control details, compressors, coils, dampers, setpoints, filters, economizers, minimum ventilation control,

control type, noise and vibration criteria, tie-in to other systems, sequences of operation under all modes of operation, control strategies, etc.)

- Equipment maintainability
- Fire, life, safety: criteria, general strategy narrative and detailed sequences
- Emergency power control and function
- Energy performance
- Ventilation strategies and methods
- Complete sequences of operation, including setpoints and control parameters
- Schedules
- Applicable codes and standards
- Primary load and design assumptions
 - Diversity used in sizing
 - Occupant density and function
 - Indoor conditions (space temperature, relative humidity, lighting power density, ventilation and infiltration rates, etc.)
 - Outdoor conditions
 - Glazing fraction, U-value and shading coefficient

Information of secondary importance to the commissioning and operation of the building should be documented by the design team, but is not included in the design documentation described here or included in the O&M manuals (e.g., wall R-values, mass, etc.)

The detail of both the design intent and basis of design increase as the design process progresses, as described in Table 5-2. In the beginning, the design documentation required is primarily a narrative of the building system descriptions, the purpose of the systems, how the systems will meet those objectives and why this system or method was chosen above others. As the design process progresses, the design documentation includes the basis of design, a specific description of the system and components, its function, how it relates to other systems, sequences of operation, and operating control parameters.

Each contributing designer clearly documents in writing the intent behind the chosen design and the operating parameters of the system. The design intent required here is not a substitute for what may be required in the specifications or contract for other systems.

Table 5-2. Progression of Design Documentation

Stage	Issues Addressed	Responsible Parties
Programming	The owner's and tenant's needs are identified in detail. The applicable parts of the programming report become the initial design intent.	Owner Architect
Conceptual Design and Design Dev.	Design intent clarified. Basis of design begun: overall system descriptions, objectives of systems, general methods of achieving objectives, etc.	Owner Architect

Construction Documents and Specification Development	Same as Conceptual Design and Design Dev. above, but in more detail, including complete basis of design: complete system & component description, specific methods of achieving system objectives, design & load assumptions, applicable codes and standards, complete sequences of operation and control strategies	Architect Design Engineers
As-Built Documentation	Same as Construction Documents and Specification Development, plus: Adjusted sequences with final control parameters	Design Engineers Installing Contractors Building Operator Architect

The initial design intent from the programming phase is developed by the architect with review by the design team and commissioning agent. The architect, or other assigned party, acts as the design documentation task lead and coordinates the creation of the full design documentation by the design team. Each member of the team provides the written basis of design and detailed sequences of operation for the areas of design that are their responsibility. They submit the documentation in parts to the task lead at the pre-determined phases of design. The architect, task lead and commissioning agent review, comment on and approve the submissions. Design intent documentation for other components and systems such as structural, interior design, furnishings, plumbing, etc. may be required, but are not a part of the commissioning work unless listed and checked herein. The full sequences of operation from the basis of design shall be included in the bid specifications.

Design Documentation Submitted:

By the Architect

- ☐ general building design and function
- ☐ interior lighting
- ☐ building shell efficiency
- ☐ environmental sustainable construction
- ☐ landscaping / irrigation

By the HVAC Mechanical Designer/Engineer

- ☐ HVAC systems (air and water)
- ☐ automatic controls
- ☐ fire/smoke protection systems
- ☐ thermal comfort
- ☐ air quality
- ☐ acoustical quality

By the Electrical Designer/Engineer

- ☐ interior lighting
- ☐ automatic lighting controls (exterior and interior)
- ☐ security system

- ___ communications system
- ___ fire and smoke alarm system
- ___ power quality
- ___ emergency power
- ___
- ___

Documentation Format and Detail

The format and rigor of the design intent documentation will be similar to the example documentation format found in the Design Documentation Format Form in Appendix 1 of this plan. The design team follows the example format and level of detail for, at a minimum, the systems checked above. The general outline of the full documentation is:

- A design narrative describing the system in general
- The objectives of each system and its functional use
- The full sequence of operations under all modes and conditions
- The setpoints and operating parameters
- Performance criteria and applicable codes and standards

Reporting and Review

Each team member submits his or her design documentation to the architect at the end of the phase listed in the example design documentation format in Appendix 1 (Design Development Phase, Construction Documents for Specification Development). The architect provides a copy of the design intent to the GSA Project Manager and to the commissioning agent. Documentation listed to be completed in the As-Built stage is not provided during design. The commissioning agent reviews the documentation and provides written comments, through the architect, to each designer. Each designer makes necessary changes according to the commissioning agent request and resubmits the documentation to the commissioning agent, through the architect.

At the end of Design, the architect compiles and submits the full design intent documentation to the commissioning agent and to the GSA Project Manager. Team members include their full sequences of operation in their bid document specifications. A draft copy of the full design intent and basis of design are provided to the commissioning agent at the beginning of construction. A final as-built copy is prepared and is included in the O&M manuals at the end of construction.

Sequences of Operation

Detailed written sequences of operation shall be developed with the following components clearly and completely described for each piece of dynamic equipment:

- An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function
- All interactions and interlocks with other systems
- Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable
- Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative.)
- Startup sequences

- Warm-up mode sequences
- Normal operating mode sequences
- Unoccupied mode sequences
- Shutdown sequences
- Capacity control sequences and equipment staging
- Temperature and pressure control: setbacks, setups, resets, etc.
- Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
- Effects of power or equipment failure with all standby component functions
- Sequences for all alarms and emergency shut downs
- Seasonal operational differences and recommendations
- Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment
- Schedules, if known
- All sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

Fire and Emergency Power Response Matrix

An HVAC fire and emergency power response matrix that lists all equipment and components (air handlers, dampers, valves, etc.) with their status and action during a fire alarm and under emergency power shall be developed. An example of a fire and power response matrix and flow chart are found in Appendix 2.

5.5 Task 5. Draft Commissioning Plan for Construction

When the drawings, traditional specifications (non-commissioning) and design intent documentation are partially complete, prior to developing commissioning specifications, the commissioning agent uses the *Model Commissioning Plan—Construction Phase* (Part IV of the *Model Commissioning Plan and Guide Specifications*) to develop the draft construction phase commissioning plan for this project. The plan contains a list of the systems and specific equipment and components to be commissioned and the general modes to be tested with the probable testing method. In addition, sections of standard language regarding process, responsibilities, O&M documentation, training and scheduling are included.

The parts in the construction phase commissioning plan with blanks that need to be filled in *prior* to construction bidding are noted to the right of the section heading with “[Bid Docs].” Other fill-in blanks are not filled in until after construction begins.

When completed, this draft (Draft 1) of the construction phase plan, provides the general scope for the construction commissioning specification development (Task 7). Then, after all drawings and specifications are complete, the commissioning agent updates the construction-phase Commissioning Plan (which becomes Draft 2). Draft 2 of the commissioning plan is included as part of the construction bid documents.

The GSA project manager and construction manager review both drafts of the plan and the commissioning agent makes recommended changes.

5.6 Task 6. Commissioning Specification Development

Commissioning specifications for inclusion in the construction bid documents are developed by members of the design team as part of the commissioning process during design.

Purpose

The specifications provide detail so that those bidding on the project can clearly understand how the commissioning process works and specifically what role they have in the process. They provide the requirements and process for properly executing the commissioning work.

Specification Content

The commissioning specifications shall provide the bidders a clear description of the extent of the verification testing required, including what components and systems will be tested and the documentation, reporting and scheduling requirements. Details of the extent of testing and who is responsible for writing tests, executing tests, witnessing and signing-off on tests shall be included. The relationship between and requirements for start-up, prefunctional checklists, manual functional performance tests, control system trend logs and stand-alone data logging shall also be given. Example tests shall also be provided. The specifications shall also detail the operator training and the O&M documentation and any O&M plan requirements. Any specific program of tasks focusing on indoor air quality should be included in the specifications.

Guide Specifications

Each designer uses the *Guide Commissioning Specifications*, adapts them for this project and includes them in specifications. Draft 1 of the *Commissioning Plan—Construction Phase* as explained in Task 5 is used to guide the commissioning specification development. This plan was developed earlier in the design process.

Coordination, Reporting and Review

The responsibilities for developing the individual sections of the commissioning specifications are listed in Table 4-1. The Specification Overview section in Part III, *Commissioning Guide Specifications*, of the *Model Commissioning Plan and Guide Specifications* provides a listing of what needs to be addressed in each specification section. The commissioning agent coordinates the commissioning specification effort and provides assistance as needed to all team members. Each team member submits the full specification of any division that includes references to commissioning, in electronic format, hard copy format to the commissioning agent for review at least two weeks prior to the printing of final specifications. Each page contains the filename and date of the document. A list is provided of any areas where the commissioning specifications deviate significantly from the guide specifications and the rationale for the deviation. Each team member also provides an electronic copy, hard copy to the architect and to the GSA Project Manager.

The commissioning agent reviews the specifications and provides written comments to each designer who edits the specifications according to the commissioning agent request and resubmits edited sections to the commissioning agent. The printed edited sections show the filename and date automatically printed on each page. The commissioning agent notifies each designer in writing of the approval of his or her commissioning specification. The commissioning agent provides to the architect in writing, the filenames and dates of the approved specification sections of each designer, which must precede printing of the final specifications. Though the

commissioning agent coordinates and reviews the commissioning specifications, the ultimate responsibility for their content and preparation lies with the A/E.

5.7 Task 7. General Review of Drawings and Specifications

The commissioning agent, along with the traditional design team members, reviews the full set of Construction Documents and specifications when approximately 50% and 95% complete. Parts of this review dealing with commissioning specifications will have been completed in Task 6—Commissioning Specification Development. The architect provides the necessary documents to the commissioning agent.

The commissioning agent compares the design with the interests and needs of GSA as identified in the programming report of the Programming and Conceptual Design Phases. The commissioning agent also compares the proposed design against the GSA design guide (PBS-PQ100.1, *Facilities Standards for the Public Buildings Service*) for the design areas checked in Table 5-3. The commissioning agent also identifies any improvements that can be made in areas that do comply with, or are not specifically mentioned in the design guide in areas checked in Table 5-3. The rigor of the review listed for the commissioning agent in Table 5-3 provides general guidance.

Though the commissioning agent may review the areas checked below, they are not *responsible* for design concept, design criteria or compliance with codes. The commissioning agent does not *verify* the designers' calculations or proof schematics or layouts in detail. The constructibility review is performed by another party. The commissioning agent will use his or her expertise to provide input into the areas checked in Table 5-3. For example, the commissioning agent does not verify appropriate pipe or duct sizing, but may provide comments on unusually tight or restrictive duct layouts and bends or a poor location of a static pressure sensor.

For the non-commissioning specifications and all the drawings, the commissioning agent provides written comment to the architect within ____ days from receiving the documents. The commissioning specification review is detailed in Task 6. The commissioning agent also provides a copy of the comments to the GSA Project Manager. The architect provides a written response to the commissioning agent and GSA Project Manager as to how the comments will be reflected in the final bid documents.

Table 5-3. Commissioning Agent Drawing and Specification Review (50% & 95%), Task 7

Design Area	Review Description	Rigor
___ Commissioning facilitation	Input regarding making the building easier to commission (see Commissioning Facilitation under Section 5.7)	___ moderate ___ rigorous
___ Component energy efficiency	Review for adequacy of the efficiency of bldg. shell components, HVAC systems and lighting systems.	___ moderate ___ rigorous
___ Control system & control strategies	Review ___ HVAC, ___ lighting, ___ fire control, ___ security control system, strategies and sequences of operation for adequacy and efficiency.	___ moderate ___ rigorous
___ Operation and maintenance	Review for effects of specified systems and layout toward facilitating O&M (equipment accessibility, system control, etc.).	___ moderate ___ rigorous

Design Area	Review Description	Rigor
___ Indoor environmental quality ¹	Review to ensure that systems relating to ___ thermal, ___ visual, ___ acoustical, ___ air quality comfort, ___ air distribution are in accordance with the design intent.	___ moderate ___ rigorous
___ Environmental sustainability	Review to ensure that the ___ building materials, ___ landscaping, ___ use of water resources, ___ waste management are in accordance with the design intent.	___ moderate ___ rigorous
___ Functionality for tenants	Review to ensure that the design meets the functionality needs of the tenants.	___ moderate ___ rigorous
___ Life cycle costs	Perform a ___ qualitative, ___ quantitative lifecycle assessment of the primary competing systems relative to ___ energy efficiency, ___ O&M, ___ IEQ, ___ functionality.	___ moderate ___ rigorous
___ O&M documentation	Verify that building O&M plan and documentation requirements specified are adequate	___ moderate ___ rigorous
___ Training	Verify that operator training requirements specified are adequate.	___ moderate ___ rigorous
___ Commissioning specifications	Verify that bid documents adequately specify building commissioning and that there are adequate monitoring and control points specified to facilitate commissioning and O&M (trending capabilities, test ports, control points, gages and thermometers).	___ moderate ___ rigorous
___ Review of engineering assumptions	Review the engineering assumptions relating to equipment sizing, energy efficiency decisions and HVAC cost-benefit calculations	___ moderate ___ rigorous

¹ To perform this review, the commissioning agent, in consultation with the owner to establish scope, shall use the checklists provided in Appendix 3. See the disclaiming note at the bottom of Table 5-1.

5.8 Commissioning Facilitation

One of the primary tasks for the commissioning agent is reviewing the design documents to facilitate commissioning during construction. Many of the features that facilitate commissioning will also enhance ease of building operation. All items from the list below shall be considered for incorporation into the project. Some of the items in the list will be appropriate for the Design Development review, while the majority will apply to the 50% and 95% Construction Documents phase reviews. The commissioning agent will make recommendations to the design team as to which items are needed. The design team will respond in writing regarding their disposition on incorporating each item.

1. Clear and rigorous design documentation, including detailed and complete sequences of operation.
2. An HVAC fire and emergency power response matrix that lists all equipment and components (air handlers, dampers, valves, etc.) with their status and action during a fire alarm and under emergency power. See Appendix 2.
3. Access for reading gages, entering doors and panels, observing and replacing filters, coils, etc.

4. Required isolation valves, dampers, interlocks, piping, etc. to allow for manual overrides, simulating failures, seasons and other testing conditions.
5. Sufficient monitoring points in the building automation system (BAS) , even beyond that necessary to control the systems, to facilitate performance verification and O&M.
6. Adequate trending and reporting features in the BAS.
7. Pressure and temperature (P/T) plugs close to controlling sensors for verifying their calibration.
8. Pressure gages, thermometers and flow meters in strategic areas for verifying system performance and ongoing O&M.
9. Pressure and temperature (P/T) plugs at less critical areas or on smaller equipment where gages and thermometers would be over-kill.
10. Specification of the location and criteria for the VAV duct static pressure sensor and chilled water differential pressure sensor.
11. Adequate balancing valves, flow metering and control stations and control system functions to facilitate and verify reliable test and balance.
12. Uniform inlet connection requirements to VAV terminal boxes.
13. Clear and complete commissioning specifications for the construction phase.
14. Complete O&M documentation requirements in the specifications.
15. Complete training requirements in the specifications.
16. Review entire document and building information management plan from design through construction and turnover to ensure adequacy and compliance with the owner's program.

6. General Schedule

The commissioning activities are integrated into the typical design process without any real increase in the timetable of deliverables. Table 6-1 illustrates the location of the commissioning activities during design.

Table 6-1. Commissioning Schedule—Design Phase

Tasks	Programming	Conceptual Development	Design Development	Construction Documents & Specifications
1. Coordination	—————	—————	—————	—————
2. Design Phase Cx Plan		———		
a. Kick-off Meeting			———	
3. Design Dev. Review				———
4. Design Intent Doc.	———	———	———	—————
5. Construction Cx Plan				———
6. Cx Specifications				———
7. Drawing & Spec Reviews				——— ———

Part II

APPENDIX 1

Design Documentation Format

Instructions for Documenting Design Intent and Basis of Design of Energy- and Comfort-Related Systems

1 Objective

This appendix presents a format for the building designers to use in documenting the design intent and fundamental operation of the building systems they have designed. Refer to Section 3 for a narrative on the need of a written design intent and clear sequences of operation and Section 5 for an example. The design-intent documentation requested here is primarily a narrative description of the building systems, what the objectives of the systems are, and how the systems will meet those objectives. This written documentation is intended for use by the designers, the commissioning agent, the installing contractors, and the building operators. This document does not constitute the required documentation and operations manual for these systems, but is a part of the O&M manuals.

The *design intent* provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner, resulting from the programming and conceptual design phases. 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 format below merges the salient parts of the design intent and basis of design.

Following these instructions is a form that is used for structuring the format and content of the design documentation.

This design intent document format contains examples for the following issues, equipment, and systems.

1. General building design and function
 - Overview
 - Sustainable construction and environmental compatibility
 - Indoor environmental quality—thermal, air distribution, acoustics, air quality, visual quality
 - Landscaping
2. HVAC systems—general
 - Overview
 - Design conditions and load assumptions
3. Chiller system (chillers, cooling towers, pumps)
4. Boiler and heating water system
5. Roof top packaged system, including all components
6. VAV terminal units (cooling only)
7. VAV terminal units (reheat)
8. Heat recovery unit
9. Computer room AC unit
10. Daylighting controls
11. Lighting sweep control
12. Building automation system

13. Split air conditioner or heat pump
14. Emergency power system

The design documentation for components or systems not listed above should follow the general form and content of this document and should describe the system, its purpose, why it was chosen above others, how it functions, and how it relates to other components and the parameters for its operation and control, including detailed sequences of operation. For additional details, refer to *ASHRAE Guidelines 1-1989R The HVAC Commissioning Process*, ASHRAE, 1996.

The design intent document may be filled out by hand for applicable systems, with attachments when necessary, or by preparing an entirely new document using the electronic version as a template.

2 Design Documentation for This Building

Adequate documentation of the design intent and basis of design of the energy- and comfort-related systems in a building is rarely found in bid documents. It is vital, however, that design intent and sequences of operation be documented adequately. That documentation serves as the goal that testing and verification seek to achieve. In addition, the design-intent document provides valuable information over the life of the building to the different parties involved in operating, maintaining, and troubleshooting the building systems.

Following are the primary areas related to energy use and comfort for which the design intent should be defined. Under each area or building system is an outline of pertinent questions concerning what should be included in the design-intent documentation and where additional clarification is needed. Sequences of operation for all outlined dynamic systems and components should be documented. Attaching equipment manufacturers' sequences is acceptable, but these sequences will generally require additional narrative. Sample sequences are found in Section 5.

To the right of the heading for each section, the party responsible for providing the design intent is indicated, as is the phase of the design construction process during which design intent should be established. For example:

4.2 System Description

Mech Engr

Design Dev

The above sample heading indicates that the mechanical engineer or designer is responsible for developing the design narrative that follows the heading and that it should be completed during the design development stage. The responsible parties and design phases are sometimes abbreviated as in the table below. The phases of the design construction process are as follows.

Programming	Design team and GSA Project Manager meet with representatives of the occupying agency or client and determine the floor area and occupancy requirements of the building.
Conceptual Design	Architect develops block diagrams, building sizing, rough space planning and sketches of exterior types. Multiple choices are provided. Mechanical and electrical designers generally have no input in this phase.
Design Development	Additional detail is applied to the block diagrams and layouts. Interior and exterior features and finishes and general HVAC system types are determined and a rough floor plan is approved.

Construction Documents Complete architectural drawings are completed. Specifications are completed, generally using the GSA Master Spec. Bid documents are prepared.

Item	Abbreviation	Refers To
Responsible Party	Arch	Architect
	Mech Engr	Mechanical Engineer
	Elec Engr	Electrical Engineer
	Ltg Des	Lighting Designer
	Ctrl Cont	Controls Contractor
Design Phase	Program	Programming Phase
	Concept Des	Conceptual or Schematic Design Phase
	Design Dev	Design Development Phase
	Const Doc	Construction Documents Phase
	Spec Dev	Specification Development (late Const. Documents Phase)

3 The Need for Written Design Documentation

Developing a statement of design intent and basis of design (design documentation) enables the parties involved with the building to better understand the building systems and better meet their responsibilities in designing, constructing, and operating the building.

The objective of specifically identifying and developing the design intent and basis of design is to provide the parties involved with the building, at each respective stage, an understanding of the building systems so as to better perform their respective responsibilities regarding the design, construction or operation of the building.

The design documentation differs from traditional specifications in that it gives a more narrative description of the system or issue and “frames” the issue or building component with background information useful and understandable to all parties. However, design documentation often includes specifications. In general, specifications tell what is to be done on a component level, where design documentation tells why something is done and, in general, how design and operating objectives will be accomplished. Sections of the design documentation can look like specifications, especially where conventional practice is departed from, e.g., energy-efficient design and construction.

Design documentation is needed from the architect so that the design engineers can design systems and write specifications. Design documentation is needed from the design engineers and architect so that the building contractors and technicians can properly construct the building. Final design documentation is needed from the building contractors and all of the above parties so that the building operator and maintenance contractors can properly maintain the original intent of the systems’ operations over time.

The design documentation evolves from more general descriptors during the conceptual design, to more specific descriptors during actual design, to in-depth and specific descriptors during the specifying stage. The design documentation is completed by fine tuning and adding further detail and specificity for some components during the as-built documentation stage. Though design documentation for some components cannot be completed until the end of building fine-tuning, it is not warranted to allow design documentation to be general or incomplete prior to construction.

Design documentation should be as firm and complete as possible as early as possible. The following table outlines these concepts including the parties responsible for defining the design documentation.

Stage	Issues Addressed	Responsible Parties
Programming	The owner's and tenant's needs are identified in detail. The applicable parts of the programming report become the initial design intent.	Owner Architect
Conceptual Design and Design Dev.	Design intent clarified. Basis of design begun: overall system descriptions, objectives of systems, general methods of achieving objectives, etc.	Owner Architect
Construction Documents and Specification Development	Same as above, but in more detail, including complete basis of design: complete system & component description, specific methods of achieving system objectives, design & load assumptions, applicable codes and standards, complete sequences of operation and control strategies	Architect Design Engineers
As-Built Documentation	Same as above, plus: Adjusted sequences with final control parameters	Design Engineers Installing Contractors Building Operator Architect

4 Sequences of Operation

Detailed written sequences of operation shall be developed with the following components clearly and completely described for each piece of dynamic equipment:

- An overview of the system (1 or 2 paragraphs) generally describing its purpose, components and function
- All interactions and interlocks with other systems
- Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable
- Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative.)
- Startup sequences
- Warmup mode sequences
- Normal operating mode sequences
- Unoccupied mode sequences
- Shutdown sequences
- Capacity control sequences and equipment staging
- Temperature and pressure control: setbacks, setups, resets, etc.
- Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.

- Effects of power or equipment failure with all standby component functions
- Sequences for all alarms and emergency shut downs
- Seasonal operational differences and recommendations
- Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful to know during testing and operating the equipment
- Planned schedules, if known
- All sequences shall be written in small statements, each with a numerical number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

5 Example Design Narrative and Sequences of Operation

Part of the design documentation involves providing a brief overview of the system in narrative form. This is very appropriate at the beginning of the sequences of operation. The following is an example for a simple packaged boiler system with some interface with the building automation system (BAS). Additional examples are found in the Guide Specifications.

Packaged Boiler Control Sequence—Example

System Overview

The boiler water system serves the space heating needs of the entire building. Heating is achieved through reheat coils in every terminal box. There are two atmospherically vented packaged boilers which work lead / lag: one boiler when outside air temperatures are less than 65F and both boilers at temperatures below 45F (adjustable). The boilers work to maintain a constant temperature output (currently 170F), and delivery to a 3-way mixing valve which mixes return water to maintain a hot water loop temperature setpoint. Each boiler has two burners and two stages of fire per burner. There are three levels of capacity: 1) both beds low fire, 2) one bed high and one low, 3) both beds high fire.

The water is delivered by two constant speed pumps, one for each boiler. Upon failure of the lead pump or boiler, the lag will start. Most coils have 2-way valves. There are a few that have 3-way valves to allow constant speed on the pumps. Each boiler has a small blend pump that circulates water through the boiler whenever the boiler is enabled.

The boiler has packaged controls that regulate the temperature of water it is supplying to the 3-way valve, prior to mixing. Those sequences are listed in Part I, below. The building automation system (BAS) enables the boiler, controls the temperature of the supply loop through a 3-way mixing valve and performs boiler lead/lag control and hot water temperature reset. Those sequences are listed in Part II, below.

Seasonal Settings

It is expected that the boilers will be shut off during summer. During the swing seasons, if the boiler will be enabled, the firing rate control should be set as low as possible. According to Proctor Sales who supplied the boiler, condensation can occur and be a potential problem if the Firing Rate Control setting is below 160F. If the control is ever raised above 170F during winter, it should be lowered back to 160F during spring and fall, to minimize energy use. The loop

temperature (via the BAS) should be kept as low as possible and is automatically changed via a reset strategy.

Part I. Packaged Boiler Controls

Once the boiler is enabled, it tries to maintain the temperature of the output, prior to the mixing valve, at the boiler Operating Control Setpoint, in the following manner.

1. When the heating water system is enabled, via the outside air temperature setpoint (initially 65F) in the BAS, the lead boiler comes on with both burners at the high firing rate.
2. Once the water temperature climbs to the low limit setpoint of the Firing Rate Control (initially at 150F), one burner bed drops to low fire (less gas pressure). The low limit setpoint is the main dog on the low limit dial.
3. If the temperature continues to climb to the high limit setpoint of the firing rate control (initially at 160F), the other burner bed drops to low fire.
4. If the temperature continues to rise to the Operating Control setpoint (initially set at 170F), the boiler cycles OFF.
5. Upon cooling, when the temperature lowers to the Operating Control Setpoint minus the differential of 10F, the boiler starts at low fire on both beds.
6. If the temperature continues to drop to the high limit of the Firing Rate Control setting minus a fixed 10F differential, one burner bed goes to high fire.
7. If the temperature continues to drop to the lower setting (via the differential dog) of the Low Firing Rate Control setpoint, the other burner goes to high fire.

Setting recommendations: 1) Set the Operating Control Setpoint. 2) Set the High Limit of the Firing Rate Control 10F to 15F lower than the Operating Control Setpoint. 3) Set the main dog of the Low Limit of the Firing Rate Control 10 to 15F lower than the High Limit (of the Firing Rate Control), 4) Set the differential dog of the Low Limit of the Firing Rate Control to 5 to 15F below the Low Limit. 5) Set the High Limit Safety to 30F above the Operating Control Setpoint.

Boiler Safeties

8. Loss of power will shut burners OFF.
9. Low water level sensed via the water low limit control will shut burners OFF (manual reset required).
10. If the operating control fails or the sensor is bad, and the water temperature goes to 200F, the safety high limit shuts the burner off. Manual reset is required.
11. In all of the above three cases, the BAS will be sent an alarm.
12. If the electronic ignition tries to light the pilot and a flame is not sensed, the main gas valve will not open.
13. **Sensors.** The high limit safety, the Operating Control and the Firing Rate Control all have their own sensors.

Part II. Building Automation System Controlled Boiler Sequences

14. When the outside air temperature (OSAT) is less than the OSAT setpoint, initially at 65F (adjustable), the lead boiler and its integral blend pump and its associated heating water pump will start. Whenever a boiler is enabled, its associated hot water pump shall run and the lag boiler will be isolated by a automatic valve. Boilers are not scheduled by time.
15. The lag boiler isolation valve will open and the lag boiler and associated pumps will start when the OSAT is less than 45F (adjustable).
16. Via pump status monitoring, after the boiler system has been enabled and the lead pump ON status has not been established within 30 seconds, the lead pump shall stop, the lag pump shall be started and an alarm generated.
17. Via boiler status monitoring, after the boiler system has been enabled and the lead boiler ON status has not been established within 30 seconds, the lead boiler shall stop, lead boiler isolation valve close, lag boiler isolation valve open and the lag boiler shall be started and an alarm generated.
18. During unoccupied periods, during night low limit operation, the boiler will cycle ON and OFF with the air handlers to maintain the night low limit setpoint.

Hot Water Mixing Valve Control

19. The 3-way mixing valve in the hot water supply is modulated to mix return water with boiler-supplied hot water to maintain a hot water supply temperature (HWST) based on the OSAT, according to the following proportional reset schedule:

<u>OSAT</u>	<u>HWST</u>
23F	180F
70F	140F

Design Intent and Basis of Design of Energy- and Comfort-Related Systems

Project: _____

Approved: _____

_____	_____	_____
Name	Owner's Representative	Date
_____	_____	_____
Name	Commissioning Agent	Date

Overview

Following are the primary areas related to energy use and comfort for which the design intent and basis of design should be defined. The design intent provides the explanation of the ideas, concepts and criteria that are considered to be very important to the owner, coming out of the programming and conceptual design phases. 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 format below merges the salient parts of the design intent and basis of design. The design intent evolves from more general descriptors during the conceptual design, to more specific descriptors during actual design, to in-depth and specific descriptors during the specifying stage, which are finalized during the as-built phase.

Under each area or building system is an outline of pertinent questions and data needed. Sequences of operation for all outlined dynamic systems and components should be clearly documented. Attaching equipment manufacturers' sequences may be acceptable, but will generally require additional narrative.

To the right of the heading for each section, the party responsible for providing the design intent is indicated, as is the phase of the design construction process during which design documentation should be established. Refer to the Instructions section, just previous in this Appendix for full instructions.

The following abbreviations are used:

Item	Abbreviation	Refers To
Responsible Party	Arch	Architect
	Mech Engr	Mechanical Engineer
	Elec Engr	Electrical Engineer
	Ltg Des	Lighting Designer
	Ctrl's Cont	Controls Contractor
Design Phase	Program	Programming Phase
	Concept Des	Conceptual or Schematic Design Phase
	Design Dev	Design Development Phase
	Const Doc	Construction Documents Phase
	Spec Dev	Specification Development (late Const. Documents Phase)

Contents

The following systems and issues are included in this document in this order:

1. General building design and function
 - Overview
 - Sustainable construction and environmental compatibility
 - Indoor environmental quality—thermal, air distribution, acoustics, air quality, visual quality
 - Landscaping
2. HVAC systems—General
 - Overview
 - Design conditions and load assumptions
3. Chiller system (chillers, cooling towers, pumps)
4. Boiler and heating water system
5. Roof top packaged System, including all components
6. VAV terminal units (cooling only)
7. VAV terminal units (reheat)
8. Heat recovery unit
9. Computer room AC unit
10. Daylighting controls
11. Lighting sweep control
12. Building automation system
13. Split air conditioner or heat pump
14. Emergency power system

Heading Format Used at the Beginning of Each Section:

X.X Issue to be Documented *Responsible Party* *When To Do It*

1 General Building Design, Function, and Landscaping

1.1 General Building Design and Function

Architect

Design Dev

What are the general design objectives regarding energy efficiency?

Comfort and indoor environmental quality?

Sustainability and environmental compatibility?

Other:

Sequences

Architect

Spec Dev

What are the main control sequences for the watering systems that ensure water conservation?

Maintenance

Architect

Spec Dev

Are there any special instructions as to the care of the landscape elements that will enhance or degrade their energy and comfort benefits? (refer to O&M manual sections, if applicable)

1.2 Sustainable Construction and Environmental Compatibility

Design Intent

Architect

Concept Des

What are the objectives regarding sustainability and environmental compatibility?

Basis of Design-General Description and Function

Architect

Design Dev

How will the building/grounds systems meet the design intent?

1.3 Indoor Environmental Quality

Design Intent

Mech Engr

Concept Des

What are the general objectives for indoor environmental quality?

Thermal Comfort—General Description and Function

Mech Engr

Design Dev

Record the occupant activity and design temperatures for the various spaces in Table 1.

Air Distribution

Mech Engr

Const Doc

What issues were considered in choosing diffusers?

Is the return air (RA) ducted or open-plenum? Why?

Are the RA grills in every room? Why?

What special considerations are being given to spaces with high solar load regarding cooling, large glazed areas, cold-air convective drafts, etc.? What solutions were used?

Acoustics

Mech Engr

Const Doc

What is the design NC (noise criteria) sound level? Provide this information in Table 1. Are there any special acoustical considerations for any areas (areas close to the AHU, private areas, open office areas, etc.)? How will this criteria be met? (flexible duct, duct lining, fan type, lead wraps, diffuser type, TU damper type, etc.)

Noise class (NC) 35-40 for closed offices and 41-43 for open offices, recommended by ASHRAE)

Air Quality

Mech Engr

Const Doc

For the general building and individual spaces, what is the desired outside air fraction or cfm per person and the number of persons per square foot? (Provide this information in Table 1). Is the outside air (OSA) controlled by CO₂ monitors? Explain.

Can occupants adjust ventilation? How and what limits apply to what areas?

Are there any special indoor pollutant source concentrations? How are they handled? List areas served by exhaust fans, the fan size, air changes per hour and operational control.

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

Where are the outside air intakes located? Are they near any potential sources of pollutants?

Are full-drain condensate pans used in the air handler units? ☐Yes / ☐No

What other special IAQ issues were considered?

Visual Quality

Arch, Ltg Des,

Design Dev

What are the design footcandle levels for the various spaces? (Provide this information in Table 1).

Why? Is additional task lighting assumed?

Do any spaces have special glare requirements? ☐Yes / ☐No

How will they be met? (special light fixtures and lenses, fixture layout, special CRT screens, etc.)

How will glare be controlled in daylit areas?

What are the parameters and sequences of operation for the daylighting controls and dimming lights? How will occupants interact with the system (overrides, education, etc.)?

1.4 Landscaping

Architect

Design Dev

Design Intent

Describe the objectives and the elements of the specific landscape design that contribute to energy efficiency, water conservation, and comfort?

Number of sheets attached to this section: _____

Const Doc

Table 1

Reception, records, conference room, closed offices, open offices, exercise room, lunch room, inventory, stock, etc.

[illegible]

2 HVAC Systems and Design Parameters

2.1 General

Mech Engr

Design Dev

General description of the main HVAC systems and areas served.

<u>System</u>	<u>Areas Served</u>

Why were the above particular systems chosen?

Describe the level of priority given to energy conservations for the system.

2.2 Specific System Descriptions

Mech Engr

Const Doc

System	Heating / Cooling / Both	Areas Served

What is the rationale for the way the HVAC and lighting were zoned?

2.3 Load Calculations

Mech Engr

Const Doc

What outdoor design conditions were assumed for load calculations?

Summer: DB _____ WB _____ Winter: DB _____

What indoor design conditions were assumed for load calculations?

Summer: DB _____ RH _____ Winter: DB _____ RH _____

Internal load assumptions: Lighting: _____ W/sf. Misc: _____ W/sf. Other: _____

People/100 sf: _____ Btu/hr/person: sensible _____, latent _____

Ventilation: _____ cfm/person. Basis (code, etc.): _____

Infiltration: ☐ _____ cf/sf wall area, or ☐ _____ air changes per hour.

Glazing:

Orientation	% of Wall Area	Overall U	SC
N			
S			
E			
W			

What overall safety factor was used and how much diversity was assumed for the heating, cooling plant and fan size?

For redundant equipment, what redundancy criteria were used?

Number of sheets attached to this section: _____

3 Chiller System (Chillers, Cooling Towers, Pumps, Piping)**3.1 Design Intent***Mech Engr**Design Dev*

What is this chiller system used for? ☐ Supplies chilled water to air handler units to cool building space. ☐ Computer room AC units. ☒ Process chilled water

☒ Heat recovery for: _____

Other: _____

What areas of the building do the chillers serve? _____

List the areas that the chillers do not serve? _____

What types of air conditioning equipment serve the areas not served by the chillers? _____

What vibration and noise considerations are given to the location of the chillers? _____

What energy efficiency objectives are there for the chiller system? ☒ Highly efficient, ☐ Moderately efficient, ☐ Standard efficiency

What level of automatic control features are desired for this chiller system relative to automatic staging, optimization, central building automation system monitoring and control capabilities, etc.? ☐ Highly automated, ☐ Moderately automated, ☐ Minimally automated

What type of refrigerant will be used and why? _____

3.2 Basis of Design-Components Description and Methods for Meeting Design Intent**Chillers***Mech Engr**Const Doc*

Briefly describe the chiller system.

☐ Centrifugal	☐ Screw	☐ Chiller	☐ Reciprocating chiller
☐ Hermetically sealed			☐ Heat recovery
☐ Heat recovery			☐ Refrigerant type: _____
☐ Refrigerant type: _____			☐ Air cooled ☐ Water cooled
☐ Air cooled ☐ Water cooled			☐ Evaporative cooled
☐ Evaporative cooled			☐ Stages of unloading: _____
☐ Capacity control type:			☐ Other: _____
☐ Prerotation vanes			
☐ Other: _____			

How many chillers of each size are there? (size and number of each size): _____

Is there a standby / redundant chiller during design conditions? _____

What method was used for determining the design cooling load? _____

Attach load calculations and assumptions, if not given in a previous section. (Diversity, safety factor, outdoor DB, WB, indoor DB, lighting W/sf, plug loads W/sf, people/100 sf, ventilation cfm/person, infiltration rate, glazing % of wall, overall U; SC).

Describe any provisions in the chiller system for accomodating future building or load expansion.

What evidence can be provided to show the chillers are not oversized? _____

Why were they chosen to be different or equal size? _____

Was variable compressor speed seriously considered? If not, why not? _____

Was heat recovery for the chiller analyzed? _____ Why or why not? _____

What were the results of the analysis? _____

What vibration and noise considerations are given to the model and features of the chosen chillers? _____

What is the rated efficiency of each chiller at full load and the APLV, in kW/ton? _____

What rationale was used to select these efficiencies with the sizes? Were more efficient models analyzed? _____

Attach engineering or energy simulation and economic calculations for the selections.

Are the chillers intended to be staged back and forth, depending on load, to minimize energy use?

Will staging occur manually or automatically? _____

What special control strategies will be employed with the chiller system? _____

What controls will be in place to allow the lowest economical entering condenser water temperature to be realized? What other options were considered besides this strategy? _____

Fully describe the interface that the building automation system has with the chiller system: _____

What control will the building automation system (BAS) have over the chiller system?

☐ BAS enables/disables the chiller, ☐ assigns the lead chiller, ☐ assigns the lead primary chilled water pump, ☐ assigns the lead secondary chilled water pump, ☐ assigns the lead condenser pump, ☐ assigns the lead cooling tower

The BAS monitors the following: ☐ LCHWT, ☐ RCHWT, ☐ ECDWT, ☐ LCDWT, ☐ CDW flow, ☐ CHW primary flow, ☐ Secondary CHW flow, ☐ Cooling tower bypass valve, ☐ Chiller alarms that report to BAS (list): _____

Other _____

The BAS can change the following: ☐ LCHWT setpoint, ☐ Reset parameters, ☐ ECDWT setpoint, ☐ Cooling tower fan staging parameters, ☐ Chilled water pumping pressure setpoints, ☐ Pressure reset parameters, ☐ Demand limits, ☐ Other _____

Cooling Tower

Mech Engr

Const Doc

Describe the cooling tower (cross flow, counterflow, etc.) _____

What are the sizes of the cooling towers? _____

What is the approach temperature rating of the cooling tower? _____

Why was a lower approach not chosen? _____

Attach energy and economic analyses.

Were oversized cooling towers analyzed to improve chiller efficiency? _____ Why or why not?

Attach analysis.

How many motors are there per tower fan? _____ Describe. _____

Are the motors premium efficiency? _____

How is the fan speed controlled? _____

How do the sizes of the chillers affect the sizes of the cooling towers selected? Are they paired? _____

Can two cooling towers serve one chiller? _____

How are the cooling towers staged? _____

Will condenser water flows be monitored? _____ If not, explain why. _____

Will the cooling tower be used in winter? _____ Why? _____

Air or Evaporative Cooled Condenser

Mech Engr

Const Doc

☐ Air cooled ☐ Evaporative cooled

Why was an air-cooled condenser chosen over a cooling tower? _____

Why was an air-cooled condenser chosen over an evaporative condenser? _____

Describe main features of the condensers and the chillers they serve. _____

Were more efficient models analyzed? (attach analysis) _____

Describe the staging features _____

Chilled and Condenser Water Pumps

Mech Engr

Const Doc

What pressure drop range was the piping system designed to:

☐ Very low pressure drop, ☐ Moderately low pressure drop, ☐ Standard pressure drop. Was an analysis performed for using a lower pressure drop to reduce pump size and energy use? _____ Attach analysis.

Describe the pumps chosen. Primary: _____

Secondary: _____

Condenser pumps _____

Are they equipped with premium energy-efficient motors? _____

Why or why not? _____

Were the pumps not over specified? What was the over-sizing rationale for the pumps?

☐ Potential system expansion, ☐ Safety factor, ☐ End of curve safety, ☐ All of above. Are these issues all likely to occur together? Was the end of curve safety really necessary? Could a software control loop safety achieve the same thing, allowing for a smaller pump? _____

Describe any standby or redundant pumps and their operation. _____

Will the control sequences allow for automatic changeover to the lag or standby pump upon pump failure and similarly for cooling tower fan failure or will manual valving be required? Upon failure, does the lag pump or tower start or does the chiller go down and lag chiller start. Explain fully for each:

Primary chilled water pumps: _____

Secondary chilled water pumps: _____

Condenser water pumps: _____

Cooling tower fans: _____

How is the secondary chilled water capacity controlled? ☐ Variable speed drives (VFD) on pumps, ☐ Bypass valve. If by bypass valve, explain the rationale for not using variable speed drives and attach the economic analysis. _____

For VFD's, how will the pump speed be controlled? ☐ Constant water pressure setpoint, ☐ Reset water pressure setpoint. If the pressure is not reset, why not? _____

For a VFD on pressure reset, how low of speed will the pump be allowed to go? Is this as low as possible? Explain. _____

Will chilled water flows be monitored? ☐ Primary flow, ☐ Secondary flow. If not, explain. _____

Chiller System Sequence of Operations and Operating Parameters

Mech Engr

Const Doc

Attach a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Chiller, Cooling Tower and Pumps

- List parameter conditions that initiate start-up.
- Provide a detailed narrative of the full sequence and status and action of EACH component during EACH stage of start-up: low load, medium load, high load, staging to next chiller, up to full load on all chillers, and then back down again to OFF condition. List all setpoints, delays, parameters, conditions, etc., that are required to pass through each stage. The components for which status will be given at each stage are: chiller stage and load, primary, secondary and condenser pump status, speed and flow, cooling tower stage, cooling tower bypass valve, cooling tower fans and speed, pipe pressures and setpoint resets.

Describe the sequences for the following:

- Chiller optimization staging.
- Temperature lockouts.
- Status and sequence at power outage and fire alarm.
- Effects of manual shutoff or failure of chiller, primary pump and secondary pump, condenser pump, cooling tower fan, vibration alarm.

- List all alarms.
- Include full sequences and setpoints for capacity and pressure control of the secondary chilled water system.
- Include full sequences and setpoints for condenser water temperature control and cooling tower fan control parameters.
- Cooling tower sump heater sequences, parameters and setpoints.
- List the full sequence of operation for all energy conserving strategies, including their setpoints and parameters.
- Weekend operation.
- Normal occupied and unoccupied modes.

Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For the chiller, cooling tower and pumps, the sequences are expected to be about five single-spaced, typewritten pages.

Number of sheets attached to this section: _____

4 Boilers and Heating Water System

4.1 Design Intent

Mech Engr

Design Dev

Hot Water. What is this boiler system used for? ☐ Supplies hot water to air handler units to ___heat building space, ___preheat incoming cold air. ☐ Supplies hot water to ___perimeter, ___core VAV reheat terminal units.

Steam. What is this boiler system used for? ☐ Supplies steam to air handler units to ___heat building space, ___preheat incoming cold air. ☐ Supplies hot water to ___perimeter, ___core VAV reheat terminal units.

Other: _____

What areas of the building do the boilers serve? _____

List the areas that the boilers do not serve? _____

What types of heating equipment serve the areas not served by the boilers? _____

What vibration and noise considerations are given to the location of the boilers? _____

What energy efficiency objectives are there for the boiler system? ☐ Highly efficient,
☐ Moderately efficient, ☐ Standard efficiency

What level of automatic control features are desired for this boiler system relative to automatic staging, optimization, central building automation system monitoring and control capabilities, etc.? ☐ Highly automated, ☐ Moderately automated, ☐ Minimally automated

What type of fuel will be used and why? ☐ Natural gas, ☐ Fuel oil, ☐ Other _____

4.2 Basis of Design-Components Description and Methods for Meeting Design Intent

Boilers

Mech Engr

Const Doc

The boiler is a ☐ Condensing, ☐ Forced draft, ☐ Atmospheric burner, ☐ Packaged, ☐ Other: _____

Briefly describe the boiler system.

How many boilers of each size and type are there? (list number and size): _____

Is there a standby / redundant boiler during design conditions? _____

What method was used for determining the design heating load? _____

Attach load calculations and assumptions, if not given in a previous section. (Diversity, safety factor, outdoor DB, WB, indoor DB, lighting W/sf, plug loads W/sf, people/100 sf, ventilation cfm/person, infiltration rate, glazing % of wall, overall U; SC).

Describe any provisions in the boiler system for accomodating future building or load expansion.

What evidence can be provided to show that the boilers are not oversized? _____

Why were they chosen to be different or equal size? _____

What vibration and noise considerations are given to the model and features of the chosen boilers? _____

How many total stages of capacity does each boiler have? (burner beds and stages of fire) _____

What is the rated efficiency of each boiler? _____

What rationale was used to select these efficiencies with the sizes? Were more efficient models analyzed? _____

Attach engineering or energy simulation and economic calculations for the selections.

Are the boilers intended to be staged back and forth, depending on load, to minimize energy use?

Will this be done manually or automatically? _____

What special control strategies will be employed with the boiler system? _____

Fully describe the interface that the building automation system has with the boiler system: _____

What control will the building automation system (BAS) have over the boiler system?

☐ BAS enables/disables the boiler, ☐ assigns the lead boiler, ☐ assigns the lead primary boiler pump, ☐ assigns the lead secondary boiler water pump.

The BAS monitors the following: ☐ boiler alarm status, ☐ pump status, ☐ internal water temperature, ☐ steam pressure, ☐ HW primary flow, ☐ secondary HW flow, ☐ three-way mixing valve, ☐ boiler alarms that report to BAS (list): _____

Other _____

The BAS can change the following: ☐ LHWT setpoint, ☐ Reset parameters, ☐ Boiler water pumping pressure setpoints, ☐ Pressure reset parameters, ☐ Demand limits, ☐ Other _____

Will the boilers have low water cutout controls? _____

4.3 Heating Water Pumps

Mech Engr

Const Doc

What pressure drop range was the piping system designed to:

☐ Very low pressure drop, ☐ Moderately low pressure drop, ☐ Standard pressure drop. Was an analysis performed for using a lower pressure drop to reduce pump size and energy use? _____ Attach analysis.

Describe the pumps chosen. Primary: _____

Secondary: _____

Are they equipped with premium energy-efficient motors? _____

Why or why not? _____

Were the pumps not over specified? What was the over-sizing rationale for the pumps?

☐ Potential system expansion, ☐ Safety factor, ☐ End of curve safety, ☐ All of above. Are these issues all likely to occur together? Was the end of curve safety really necessary? Could a software control loop safety achieve the same thing, allowing for a smaller pump? _____

Describe any standby or redundant pumps and their operation. _____

Will the control sequences allow for automatic changeover to the lag or standby pump upon pump failure or will manual valving be required? Explain fully.

Primary heating water pumps: _____

Secondary heating water pumps: _____

How is the secondary heating water capacity controlled? ☐ Variable speed drives (VFD) on pumps, ☐ Bypass valve(s). If by bypass valves, explain the rationale for not using variable speed drives and attach the economic analysis. _____

For VFD's, how will the pump speed be controlled? ☐ Constant water pressure setpoint, ☐ Reset water pressure setpoint. If the pressure is not reset, why not? _____

For a VFD on pressure reset, how low of speed will the pump be allowed to go? Is this as low as possible? Explain. _____

Will heating water flows be monitored? ☐ Primary flow, ☐ Secondary flow. If not, explain. _____

How is supply water temperature controlled? ☐ 3-way mixing valve, ☒ Other _____

4.4 Boiler System Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Attach a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

- List parameter conditions that initiate start-up.
- Provide a detailed narrative of the full sequence and status and action of EACH component during EACH stage of start-up: low load, medium load, high load, staging to next boiler, up to full load on all boilers, and then back down again to OFF condition. List all setpoints, delays, parameters, lockouts, conditions, etc., that are required to pass through each stage. The components for which status will be given at each stage are: boiler stage and load, primary, secondary pump status, speed and flow, pipe pressures and setpoint resets.

Describe the sequences for the following:

- Boiler optimization staging.
- Temperature lockouts.
- Status and sequence at power outage and fire alarm.
- Effects of manual shutoff or failure of boiler, primary pump and secondary pump.
- List all alarms.

- Include full sequences and setpoints for capacity and pressure control of the secondary heating water system.
- List the full sequence of operation for all energy conserving strategies, including their setpoints and parameters.
- Weekend operation.
- Normal occupied and unoccupied modes.
- Warm-up mode

Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For the boiler and pumps, the sequences are expected to be about ____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

5 Roof Top Packaged System(s) (RTU)

5.1 Design Intent

Mech Engr

Design Dev

What is this system or component used for? _____

Systems Description

Mech Engr

Const Doc

Briefly describe the system:

☐ Heat pump	☐ Steam
☐ Gas pack	☐ Constant volume
☐ AC only	☐ Dual duct
☐ Resistance coil	☐ Multizone
☐ Hot water	☐ Other _____
☐ VAV	☐ Other _____

List equipment and areas served: _____

5.2 Basis of Design-Components Description and Methods for Meeting the Design Intent

Mech Engr

Const Doc

Give size, quantity, and other specific information and the areas served, and how it will meet the objectives.

Plant

Number of units of this type: _____ EER (cooling): _____ Tons cooling each unit: _____

Accumulated capacity for all units of this type: Total tons cooling: _____

MBtu heating: _____ Heat Pump COP: _____ Gas efficiency: _____

Areas served: _____

Supply Fans and Capacity Control

Total CFM for packaged systems of this type: _____

☐ Inlet vanes ☐ VFD ☐ Vane axial ☐ Outlet damper ☐ Other: _____

Motor efficiency: _____ Std. effic., _____ Premium effic.

Return Fans / Exhaust Fans / Relief Dampers

Describe return fans, exhaust fans, or relief dampers, if any, and their function.

Describe how building static pressure is controlled (setpoints, etc.). _____

VFD control:

Which fans does each VFD control? ☐ Supply ☐ Return/Exhaust

Location of duct static-pressure sensor (distance from fan and proximity from branch takeoffs up and down stream): _____

Duct static pressure: ☐ Fixed setpoint / ☐ Reset or variable

Expected duct static pressure setpoint (or average if reset): _____

Total pressure across fan at design flow: _____ [discharge pressure - suction pressure (negative)]

Minimum fan capacity (lower frequency limit setting in VFD, % of max.) _____

Are VFD settings ☐ monitored or ☐ controlled by the BAS system? (check one)

Method used for sizing ducts _____ equal friction _____ static regain

Note: Equal friction gives smaller ducts and higher pressure requirements.
If equal friction was used, was a calculation made to make sure the increased pressure and subsequent increase in energy use by the fan is more than offset by the savings in duct materials? _____

Compressor(s)

Number of compressors per RTU: _____. Low ambient compressor package? _____

Number of condenser fans per RTU: _____

Compressor capacity control; general description: _____

Cooling coil

Provide general description and any special features (high efficiency, face velocity, low pressure drop, etc.). Was a low pressure drop coil analyzed? What were the results?

Dampers

Describe the dampers and their function. _____

Smoke and Fire Dampers

Describe the smoke and fire damper system (location and operation). _____

Setpoint Temperatures

Supply air (SA): _____ SA reset (see strategy sequence): _____ Mixed air: _____

Filters

Provide general description and any special features (low pressure drop, etc.). Were low pressure drop filters analyzed? What were the results? _____

Heating System

Describe type, fuel, perimeter reheat, areas served, etc.

Economizer and OSA Dampers

☐ Enthalpy ☐ Dry Bulb ☐ Integrated ☐ Economizer is first stage of cooling

Number of damper positions: ☐ _____ or ☐ infinite.

Dampers closed during warm-up? ☐ Yes / ☐ No

If dry-bulb type: OSA changeover temperature: _____

Other special features of the RTU:

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
Mixed air temp.	_____	_____	Compressor stage	_____	NA
RA temp.	_____	NA	Bldg. static pressure	_____	_____
SA temp	_____	_____	Temp. lockouts	_____	_____
SA reset parameters	_____	_____	CO ₂ for OSA control	_____	_____
RA enthalpy	_____	NA	Htg. coil position	_____	NA
DA static pressure	_____	_____	Optimum start	NA	_____
Duct static pressure	_____	_____	Night purge	NA	_____
Supply fan statuc	_____	NA	Demand limit	NA	_____
Ret./Exh. fan status	_____	NA	Alarms (list):	_____	_____
Supply fan speed	_____	NA	-Dirty filter	_____	_____
Ret./Exh. fan speed	_____	NA	-Compressor fail	_____	_____
Supply fan cfm	_____	NA	-Fan loss of air	_____	_____
Ret./Exh. fan cfm	_____	NA	-High DA pressure	_____	_____
Inlet vane position	_____	NA	-Fire/smoke	_____	_____
Filter Diff. pressure	_____	_____	-Emerg. shutdown	_____	NA
Occup. schedule override	_____	_____	OSA compensation for VAV	_____	_____
Night low limits	_____	_____	OSA economizer	_____	_____
_____	_____	_____	_____	_____	_____

Describe other equipment tied to the ON/OFF status of the RTU (exhaust fans, etc.)

5.3 RTU Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Systems

- supply fans
- exhaust fans
- return air and exhaust dampers
- supply air capacity control
- economizer and OSA dampers
- building static pressure control
- coil valve operation
- CO₂ sensor OSA control
- smoke dampers

Conditions or Modes

- start-up
- shut-down
- normal occupied & unoccupied periods
- warm-up
- temperature lockouts
- compressor and condenser staging
- override sequences
- winter/summer changeover
- weekend operation
- normal operation heating
- normal operation cooling
- through deadband ranges
- alarms: fire, smoke, shutdown, equip. failure, temp. and pressure limits, etc.
- all energy conserving strategies (optimum start/stop, resets, etc.)
- fire alarm

Include the position or status at which each component resides at start-up, what occurs at fire alarm, provide all setpoints and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate. Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

For this RTU system, these sequences are expected to be about _____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

6 VAV Terminal Units—Air Conditioning Only (TU_AC)

6.1 System Description

Mech Engr

Design Dev

Briefly describe the TU: _____

Number of TU_ACs: _____ Type of area served: _____

TU type: ☐ pressure independent / ☐ pressure dependent

Minimum air damper position: _____% open.

Are these fan powered? _____. ☐ Parallel, ☐ Series. Why? _____

TU measures air flow via total and static pressure sensors. Y/N ____.

☐ Cross, ☐ Linear flow station? Other flow method: _____

Describe TU controller type: _____

Damper actuator type: ☐ Electric, ☐ Pneumatic.

What noise considerations were used when specifying the TU's? _____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
TU air flow	_____	_____	TU air flow max.	_____	_____
TU air flow min.	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

6.2 TU_AC Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations (including all sequences, deadband, alarm actions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

7 VAV Terminal Units—Reheat (TU_RH)

7.1 System Description

Mech Engr

Design Dev

Briefly describe the TU: _____

Number of TU_RHs: _____ Type of area served: _____

TU type: ☐ pressure independent / ☐ pressure dependent

Are these fan powered? _____. ☐ Parallel, ☐ Series. Number of fan speeds? _____

Why? _____

What provisions will be made to minimize reheat? _____

What provisions will be made to minimize system simultaneous heating and cooling? _____

TU measures air flow via total and static pressure sensors. Y/N ____.

☐ Cross, ☐ Linear flow station? Other flow method: _____

Minimum air damper position: _____% open.

When the damper is at minimum in heating and space setpoint is not being maintained, will dampers open? _____ Why? _____

Describe TU controller type: _____

Damper actuator type: ☐ Electric, ☐ Pneumatic.

Heating coil type: ☐ hot water, ☐ electric resistance and stages ____.

Describe heating coil valve: ☐ Two position, ☐ Modulating. _____

Heating valve actuator type: ☐ Electric, ☐ Pneumatic.

Do some units have 3-way valves? Why? _____

Automatic flow control valve? ____ Describe: _____

What noise considerations were used when specifying the TU's? _____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
TU air flow	_____	_____	TU air flow max.	_____	_____
TU air flow min.	_____	_____	Valve position	_____	_____
_____	_____	_____	_____	_____	_____

7.2 TU_RH Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations (including heat lockout parameters, heating valve sequences, deadbands, alarm actions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

8 Heat Recovery Unit (HRU)

8.1 Design Intent

Mech Engr

Design Dev

Describe the purpose of the HRU: _____

8.2 System Description

Mech Engr

Design Dev

Briefly describe the system: _____

On which air handlers does this system operate? _____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

8.3 HRU Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations (including seasonal variations) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

9 Computer Room Conditioning Unit (ACU)

9.1 Design Intent

Mech Engr

Design Dev

What is this system or component used for?

General Description

Mech Engr

Design Dev

Briefly describe the system or component.

9.2 Basis of Design-Component Description and Methods for Meeting the Design Intent

Mech Engr

Design Dev

Areas served: _____

Number of ACUs: _____ Sizes (tons) _____ EER: _____

Location of ACU: _____

☐ Ducted system or ☐ discharge only? _____

How is heat rejected? ☐ Cooling tower / ☐ DX air-cooled condenser / ☐ Other

Location of condenser: _____

Humidifier description: _____

Reheat description: _____

How is the ACU controlled?

- ☐ Stand-alone controllers with thermostats in zones
- ☐ Same, but enabled/disabled by central building automation system
- ☐ "fully" controlled by BAS

Does supply air enter this space from the main HVAC system? ☐ Yes / ☐ No

If Yes, when? _____

How is fresh air brought into and controlled in the space? _____

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

9.3 ACU Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations (including setpoints, unoccupied, occupied, fire alarm periods, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

10 Daylighting Controls

10.1 Design Intent

Elec Engr

Design Dev

Briefly describe the system: _____

What is the primary reason for using daylighting? ☐ energy savings / ☐ view/aesthetics
☐ visual light quality

What budget limitations were there? _____

10.2 Basis of Design

Elec Engr

Design Dev

System type: ☐ continuous dimming / ☐ stepped dimming in ____ steps

Describe related architectural features such as light shelves, sloped ceilings, skylights, special interior finishes, etc. _____

How low are the lights allowed to dim? _____%.

The system is controlled by: ☐ main BAS / ☐ stand alone controllers

What is the light level setpoint(s) at the work plane:

<u>Area</u>	<u>Design Foot Candles</u>
_____	_____
_____	_____
_____	_____
_____	_____

How deep into the building do the lights dim? _____ft.

Are the dimming rates the same across this distance? ☐ Yes / ☐ No

Explain: _____

What areas of the building have dimming control?

How many zones and controllers (light sensors) are there? _____

How do occupants override the dimming? _____

Who has access for adjusting light levels? _____

Where are these adjustments made? _____

Where are the sensors located? _____

10.3 Sequence of Operations and Operating Parameters

Elec Engr

Spec Dev

Provide a full and comprehensive sequence of operations (including setpoints and occupied and unoccupied conditions, etc.) on a separate sheet(s) and attach to this section of the form.

Number of sheets attached to this section: _____

11 Lighting Sweep Control

11.1 System Description

Elec Engr, Ctrls Cont, Design Dev

Briefly describe the system: _____

11.2 Operating Parameters

Elec Engr, Ctrls Cont, Spec Dev

The system is controlled by: ☐ Main BAS / ☐ Stand-alone controller

How many zones will there be? _____

What is the floor area of the largest zone? _____

How many sweeps will there be? _____

At what times?

Weekdays: _____

Saturday: _____

Sunday: _____

Describe the type of switching system that occupants will use to turn the lights back on in their zone.

What is the maximum override duration? _____ hours

Who will be able to globally override the sweeps or change the schedule?

How will the sweeps work with housekeeping schedules? _____

Number of sheets attached to this section: _____

12 Building Automation System (BAS)

12.1 Design Intent

Mech Engr, Ctrls Cont Design Dev

Briefly describe the system: _____

Why was this system chosen over others considered? _____

Describe any budget limitations: _____

How important was energy conservation in the decision of BAS type? _____

12.2 Basis of Design—Component Description and Methods for Meeting the Design Intent

Mech Engr, Ctrls Cont, Const Doc

Central system is: ☐ DDC, ☐ pneumatic

Valve actuators: ☐ electric, ☐ pneumatic. AHU damper actuators: ☐ electric, ☐ pneumatic

VAV terminal box damper actuators: ☐ electric, ☐ pneumatic

Fire / smoke damper actuators: ☐ electric, ☐ pneumatic

User interface: ☐ graphical display of components

Limitations of the modules or features specified, compared to the highest model line system:

Check the systems that the BAS will control (vs local equipment, packaged controllers). Refer to the individual system section for a complete description of the points and their control by the BAS

	Virtually Full Control	Partial Control	Enable/Disable Only	Monitor Only
Rooftop packaged unit	☐	☐	☐	☐
Air handler unit	☐	☐	☐	☐
Economizer functions	☐	☐	☐	☐
Boiler plant	☐	☐	☐	☐
Heating water pumping system	☐	☐	☐	☐
Chiller plant	☐	☐	☐	☐
Chilled water pumping system	☐	☐	☐	☐
Cooling tower	☐	☐	☐	☐
Condenser water pumping	☐	☐	☐	☐
Terminal unit settings	☐	☐	☐	☐
Heat recovery unit	☐	☐	☐	☐
Daylighting setpoints	☐	☐	☐	☐
Lighting sweep control	☐	☐	☐	☐
Exterior lighting	☐	☐	☐	☐
Computer room HVAC unit	☐	☐	☐	☐
Fan coil unit and condenser	☐	☐	☐	☐
Unit heaters	☐	☐	☐	☐
Smoke and fire control	☐	☐	☐	☐
Emergency power system	☐	☐	☐	☐
UPS power system	☐	☐	☐	☐
Service water heating pump	☐	☐	☐	☐
_____	☐	☐	☐	☐
_____	☐	☐	☐	☐
_____	☐	☐	☐	☐

Location of user interface: _____

Type of user interface:

- ☐ Permanent on-site computer terminal
☐ Plug-in portable computer
☐ Remote terminal of _____
☐ Keypad only

Describe parties who will be able to change schedules only: _____

Describe parties who will have full access to system: _____

Check the energy conserving control strategies that will be operational in this building through the BAS.

☐ Holiday scheduling	☐ Occupancy-based outside air control
☐ Zonal scheduling	☐ DX compressor optimization
☐ Sequential startup of equipment	☐ Mixed air temperature control
☐ Lighting sweep	☐ Boiler staging and optimization
☐ Night setup/setback	☐ Heat element (coil) staging
☐ Optimum start	☒ Hot water reset
☐ Optimum stop	☐ Heat recovery option control
☐ Hot & cold deck reset (supply air)	☐ Water-side economizer control
☐ Chilled water reset	☐ Variable speed pump control
☐ Chiller staging and optimization	☐ Occupancy based HVAC control
☐ Cooling tower component staging	☒ Terminal regulated air volume (TRAV)
☐ Air-side economizer control	☐ Thermal storage control
☐ Night ventilation purge / pre-cooling	☐ Demand limiting or load shedding
☐ CO2 outside air rate control	☐ Duty cycling of equipment
☐ VAV control-pressure independent	☐ DHW recirculation pump control
☐ VAV control-pressure dependent	☐ DHW temperature control
☐ Duct static pressure reset	☐ Full trending capabilities
☐ _____	☐ _____
☐ _____	☐ _____
☐ _____	☐ _____

List all special monitoring points installed for diagnostic, performance verification and trouble shooting purposes, which are not needed to execute the control sequences and strategies?

12.3 BAS Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations, including setpoints, deadbands, etc. List full control sequences for all control strategies. Refer to sequences already provided in other component sections, if applicable. List on a separate sheet(s) and attach to this section of the form.

Include the position or status at which each component resides at start-up, provide all setpoints and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate. Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Section 4 of the instructions.

Note: Complete BAS description, points list with all details, program listing, etc. are not part of the design intent, but will be required as part of the O&M documentation.

12.4 Points List

Mech Engr, Ctrls Cont Spec Dev

For this design intent, list all points in a table that includes at *least* the information shown in the following example table.

Controlled System	Point Abbr.	Point Description	Display Units	Control or Setpoint Y/N	Monitoring Point Y/N	Intermediate Point Y/N	Calculated Point Y/N

Key:

Point Description: DB temp, airflow, etc.

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

Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).

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

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

Number of sheets attached to this section: _____

13 Split ___ Air Conditioning; ___ Heat Pump System

13.1 Design Intent

Mech Engr

Design Dev

What is this system or component used for? _____

Systems Description

Mech Engr

Const Doc

Briefly describe the system:

☐ DX AC only

☐ VAV

☐ Heat Pump and AC

☐ Constant volume

☐ Resistance coil

☐ Dual duct

☐ Hot water coil

☐ Multizone

☐ Gas furnace

☐ Other _____

☐ Other _____

List equipment and areas served: _____

13.2 Basis of Design-Component Description and Methods for Meeting the Design Intent

Mech Eng

Const Doc

Give size, quantity, and other specific information and the areas served, and how it will meet the objectives.

Plant

Number of units of this type: _____ EER (cooling): _____ Tons cooling each: _____

Accumulated capacity for all units of this type: Total tons cooling: _____

MBtu heating: _____ Heat Pump COP: _____ Gas efficiency: _____

Areas served: _____

Compressor(s) and Condenser(s)

Number of compressors per condenser unit: _____. Low ambient compressor package? _____

Number of condenser fans condenser unit: _____

Compressor capacity control; general description: _____

Evaporator / Cooling Coil

Provide general description and any special features (high efficiency, face velocity, low pressure drop, etc.). Was a low pressure drop coil analyzed? What were the results?

Supply Fans and Capacity Control

Total CFM for inside fan coil or air handler of this type: _____

- ☐ Constant volume ☐ Inlet vanes ☐ VFD ☐ Vane axial ☐ Outlet damper ☐ Other: _____
- ☐ Evaporator fan cycles ON and OFF with compressor. Motor efficiency: _____ Std. effc.,
_____ Premium effc.

Dampers

Describe any dampers and their function. _____

Smoke and Fire Dampers

Describe the smoke and fire damper system (location and operation). _____

Setpoint Temperatures

Supply air (SA): _____ SA reset (see strategy sequence): _____

Filters

Provide general description and any special features (low pressure drop, etc.). Were low pressure drop filters analyzed? What were the results? _____

Heating System

Describe type, fuel, perimeter reheat, areas served, etc.

Economizer and OSA Dampers

- ☐ No OSA via this unit ☐ Enthalpy ☐ Dry Bulb ☐ Integrated ☐ Economizer is first stage of cooling

Number of damper positions: ☐ _____ or ☐ infinite.

Dampers closed during warm-up? ☐ Yes / ☐ No

If dry-bulb type: OSA changeover temperature: _____

Other special features of the split system:

How will the fresh air rate be maintained at low supply air volumes of the VAV system? Are perimeter zones treated differently than interior zones (reheat box damper settings, etc.)?

How is the split system controlled?

☐ Stand-alone controllers with thermostats in zones. Number of zones: _____

☐ Above, but enabled/disabled by central building automation system (BAS)

☐ Integrated into BAS as below:

Integration of Control and Monitoring Points With the BAS

Point or Feature	BAS Monitors	BAS Can Change SetPts	Point or Feature	BAS Monitors	BAS Can Change SetPts
RA temp.	_____	NA	Compressor stage	_____	NA
SA temp	_____	_____	Temp. lockouts	_____	_____
SA reset parameters	_____	_____	CO ₂ for OSA control	_____	_____
RA enthalpy	_____	NA	Htg. valve position	_____	NA
DA static pressure	_____	_____	Optimum start	NA	_____
Duct static pressure	_____	_____	Night purge	NA	_____
Supply fan static	_____	NA		NA	_____
Ret./Exh. fan status	_____	NA	Alarms (list):	_____	_____
Occup. schedule override	_____	_____	Night low limits	_____	_____
OSA economizer	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

Describe other equipment tied to the ON/OFF status of the split system unit (exhaust fans, etc.)

13.3 Split System Sequence of Operations and Operating Parameters

Mech Engr

Spec Dev

Provide a full and comprehensive sequence of operations, including but not limited to the following conditions and systems, including all interactions:

Systems	Conditions or Modes
<ul style="list-style-type: none">• supply fans• supply air capacity control• economizer and OSA dampers• building static pressure control• coil valve operation• CO₂ sensor OSA control• smoke dampers	<ul style="list-style-type: none">• start-up• shut-down• normal occupied & unoccupied periods• warm-up• temperature lockouts• compressor and condenser staging• override sequences• winter/summer changeover• weekend operation• normal operation heating• normal operation cooling• through deadband ranges• alarms: fire, smoke, shutdown, equip. failure, temp. and pressure limits, etc.• all energy conserving strategies (optimum start/stop, resets, etc.)• fire alarm

Include the position or status at which each component resides at start-up, what occurs at fire alarm, provide all setpoints and control parameters, including all time delays. In the sequences, describe what controls what. That is, what components must be ON or at certain conditions in order for others to operate. Equipment manufacturers' sequences and control drawings may be included, but will generally require additional narrative. Flow charts may be used if sufficiently detailed. Narrative and flow chart examples are found in Sections 4 of the instructions.

For this system, these sequences are expected to be about _____ single spaced, typewritten pages.

Number of sheets attached to this section: _____

14 Emergency Power System

14.1 Design Intent

Elec Engr

Design Dev

Briefly describe the system: _____

What is the purpose of the emergency power and any UPS for each load other than the fire, life, safety loads?

14.2 Basis of Design-Component Description and Methods for Meeting the Design Intent

Elec Engr

Spec Dev

Generator

Is the generator sized to be able to handle additional loads? _____ How many? _____

What is the maximum time it should take the generator to be providing power from the time street power is lost (seconds)? _____

Is there an automatic generator exercizer? _____

For how long should the generator be able to provide power without refueling? _____

Describe any special frequency and voltage regulation output requirements for the generator. _____

Power Quality

Elec Engr

Spec Dev

Describe any special power quality concerns or considerations (sensitive equipment, etc.). _____

UPS

How many UPS systems are there? List all, including integral batteries in equipment. _____

What kind of UPS bypass will be used on the stand-alone UPS? _____

Emergency Power and UPS Schedule

Elec Engr

Spec Dev

In the following table, list each load on emergency power and/or on a UPS. List the UPS discharge time. List all the loads first that are only on emergency power.

Part II. Model Commissioning Plan—Design Phase

Appendix 1. Design Documentation Form

[illegible]

Number of sheets attached to this section: _____

15 OTHER SYSTEMS FOR WHICH TO DEVELOP SAMPLE FORMATS

Fire Alarm and Protection
Systems

Service Water Heating

Air Handler Units	Capacity control
	Supply fan
	Return/exhaust fan and dampers
	Heating and cooling coil valves
	Economizer and OSA and return air dampers
	Mixed air control

Exhaust Fans

Part II

APPENDIX 2

Fire and Emergency Power Response Matrix

--SAMPLE--

Fire and Emergency Power Response Matrix

Component	Response to Fire / Smoke Alarm			Response to a Street Power Outage		
	Alarm Type-1: Any Fire Alarm In Bldg ¹ (unless noted)	Alarm Type-2:	Controls to Use & Reset, (Manual, BAS, etc.)	Response	Control s to Use (Manual, BAS, etc.)	Manual Reset Reg'd?
Rooftop units-1,2,3;4:						
Start / Stop	Shutdown		Off--no control. Reset varies: ²	Shutdown	none	No, but smoke dprs must be open
Dampers	Go to normal: OA is closed RA is open EA is closed		na	Go to Normal	none	No
Terminal * Units	Dampers: 100% open Valves: no change		na	Dampers: stop where they are Valves: open	none	No
Split FCU-2; ACU-1	none		Normal (manual)	None (go on emergency power)	Normal (manual)	na
BAS	Receive and log an alarm		Normal	None (goes on own battery backup)	Off	na
Exh. Fans EF-1a,b, 2, 3	Off with RTU's		Override in BAS	Off	none	No
Exh. Fans EF-1c; 4	none		Normal	Off	none	Manual Timers
Boiler	none		Normal	Off	none	No
Boiler pumps	none		Normal	Off	none	No
CUH's	none		Normal	Off	none	No
Elevators	Any general alarm: go to 1st floor. SD in elev. shaft or equip. room: go to 2nd floor. SD in front of elev. on 1st floor: go to 2nd floor. Heat det. in shaft or equip. rm.: shunt trip elev. off.		Manual	Lights ON; car stops where it is	none	No
Med-Gas Vac. compr	none		Normal	Off	none	No
Med-Gas Gas compr	none		Normal	Off, but medgas alarm on emerg. gen	none	No

Normal Lighting Sys.	none		Normal	Off	none	No
Emerg. Lighting Sys.	none		Normal	None: goes on emerg. power	BAS	nao
Data Management	none		Normal	None: goes on emerg. power+UPS	Normal	na
Paging System	none		Normal	Off	none	No
Security System	Operates per normal, sending alarms		Normal	None: goes on emerg. power + on battery backup	Normal	na
Fire/Smoke Dampers	All close		auto-reset if fusible link didn't release	None: slowly leak down and close	Normal	na
Fire Doors	All close, except OH doors at pharmacy, unless 1 of 3 adjacent clg. SD alarms		manually reset	None: goes on emerg. power + on battery backup	na	na
Emerg. Gen. & UPS	none		na	Goes on-line & alarms to Security	Normal	na
Emerg. Pwr. Circuits	none		na	None: go on emerg. power	Normal	na
Fire Alarm System Functions	normal operation		na	None: goes on emerg. power + on battery backup	Normal	na
Communications to BAS	alarm sent to BAS from FAP		na	None	na	na
Communication to Outside						
Owner's Site	gets fire and trouble message via Sec. Co.		na	gets message via Security Co.	na	na
Owner's Secur	gets fire and trouble message via in-bldg Security Co's dialer		na	gets message via in-bldg Security Co. dialer, due to UPS starting'	na	na
Fire Dept.	fire alarm via Sec. Co		na	none	na	na

¹ Any Fire Alarm: (pull station, space or duct smoke detector, heat detector or sprinkler flow). This does not include trouble alarms or release of fusible links in fire dampers, or heat detection and smoke detector in elevator shaft or equipment rooms. A smoke detector trip in the elevator shaft or equipment room causes elevator to go to 2nd floor.

² A duct detector trip will cause a general alarm and will shut down all RTU's. Only RTU associated with tripped detector requires manual reset at the RTU panel. On a normal general alarm, all RTU's are automatically reset upon resetting the fire alarm panel.

--Sample--
Fire Alarm Sequence Flow Chart

11/21/96

Fire Alarm includes any initiating event (pull station, space or duct smoke detector, heat detector or sprinkler flow). It does not include fire damper fusible link release of a fire damper. Heat detector in elevator equip. room or shaft has 30 sec. delay to allow recall to floors, then power to elevator is shunt-tripped off.
Trouble Alarm includes any of the troubles listed in Appendix M of the FAP O&M.

[fire_flow.sg]

Part II

APPENDIX 3

Commissioning For Indoor Air Quality Checklist —Design Phase—

Commissioning For Indoor Air Quality Checklist

—Design Phase—

Program Phase

Document the results from each of the following tasks:

1. Determine indoor air quality requirements in accordance with the initial design intent of the owner's needs. Codes, standards: *ASHRAE Standard 62-1989, Ventilation for Acceptable Air Quality* and *Standard 55-1992 Thermal Environmental Conditions for Human Occupancy*.
2. Identify the sources of outdoor pollutants in the vicinity of the building site: general ambient air quality, exhaust systems, nearby cooling towers, smoke stacks, and existing or proposed parking garages, etc.
3. Review expected occupant activity, density and locations where special attention is needed: kitchens and break rooms, smoking lounges, photocopy and print rooms, janitorial rooms, labs, material storage rooms, and conference rooms, etc. Review the need for exhaust systems or increased supply air capacity for each area, etc.

Design Development and Construction Documents Phase

Document the results from each of the following tasks:

1. Ensure that the indoor air quality objectives established in the programming phase are included in the design and are well documented in the design intent.
2. Establish the outdoor air intake requirements for each area of the building.
3. Establish procedures for verifying and documenting ventilation rates in each area.
4. Establish air flow rates for needed exhaust systems, including spot pollutant source removal.
5. Determine how adequate ventilation rates will be maintained during all occupied modes of operations, particularly during VAV terminal box turn-down.
6. Review air intakes and exhausts for short-circuiting.
7. Review exterior pollution sources such as garages, loading docks, and cooling towers.
8. Review the impact of the office partitions configurations with respect to ventilation effectiveness.
9. Review choice of filtration type and design, materials, and location.
10. Review HVAC material specifications and application regarding potential for airflow erosion, corrosion and microbial contamination (HVAC insulation materials, etc.).
11. Review air supply system components to ensure control and minimization of the presence of free water and to minimize microbial contamination (condensate trays, humidifiers, water baffles, mist eliminators and cooling towers).

12. Verify the suitability of access doors and inspection ports to all chambers and components of air handling system plenums. Verify that proper cleaning of both sides of coils, condensate pans and/or humidifier reservoirs can be accomplished through the doors.
13. Optional: Examine manufacturer's safety data sheets (MSDS) for products specified in contract documents that may be suspected contributors to indoor pollutants (carpets, flooring, fabrics, adhesives, wall coverings, partitions, and ceilings; insulating and fire-proofing materials; sealants on walls and floors; use of preservatives, paints, varnishes, and other finish materials).
14. Obtain manufacturer's data on curing, drying and airing procedures to minimize emission rates.
15. Verify that the specifications specify proper methods and conditions for operating the HVAC system prior to full control and occupancy, to minimize dirt and unwanted moisture entering the duct work, coils, building cavities and any occupied portions of the building.

Note:

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

The primary source for this checklist was Annex C in *ASHRAE Guideline 1-1989R The HVAC Commissioning Process*, Public Review Draft, 1996.

Part III

Commissioning Guide

--Specifications--

Sponsored by
US Department of Energy
Seattle Regional Support Office
800 5th Ave. Suite 3950
Seattle, WA 98104

Prepared by:
Portland Energy Conservation, Inc. (PECI)
921 SW Washington, Suite 312
Portland, OR 97205
503-248-4636, Fax 503-295-0820

Version 2.02

March 1997

Commissioning Guide Specifications

Overview

1. General Overview

These commissioning guide specifications contain recommended language that describes both the requirements and the process to incorporate commissioning into larger construction or renovation projects. Significant process language is required because commissioning is new to many construction professionals. The specifications generally follow the ASHRAE document, *The HVAC Commissioning Process*, ASHRAE Guideline 1-1989R, final draft 1996, though significant additional detail, clarification and interpretation has been made.

The guide specifications are intended to be modified by the architect and design engineers (A/E) in consultation with the design phase commissioning agent, the project manager and the facility engineer, if known. The A/E shall modify other specification sections as necessary to reflect commissioning requirements applicable to the current project.

Abbreviations are used in the Specifications and are defined in Section 01040 and 17100, Part 1.

2. Management Scenarios

The specifications were developed for the construction management protocols of GSA, Region 10, which include:

1. The construction manager (CM) is a subcontractor to the owner (GSA) and represents the owner in the day-to-day activities and job coordination for the entire construction project.
2. GSA's staff project manager (PM) manages the CM.
3. The A/E's role during construction consists of the basic services of submittal review and periodic site observation. The A/E team is not significantly involved in performance verification or quality control. Therefore, its role in commissioning is limited to dealing with design and other problems identified during commissioning, attending selected commissioning team meetings, reviewing clarifications to the control sequences by the commissioning agent, reviewing selected functional test procedures, providing as-built design intent for the O&M manuals, and presenting at the first owner personnel training.

Other notable management and process information:

1. The specifications are applicable to a variety of commissioning agent (CA) hiring scenarios: CA hired by the CM, directly by GSA, by the general contractor (GC) or by the A/E.
2. The CA is the person directly coordinating and directing all commissioning activities on a day-to-day basis.
3. If the CA is hired by the GC or A/E, the CM will verify that the CA is properly executing the commissioning as per specification. In this case the CA reports directly to the CM.

4. If the CA is hired by the CM or directly by GSA, the verification of the CA's commissioning work in (3) is eliminated.
5. The subcontractors (under the GC) direct, execute and document their own startup and initial checkout, incorporating the CA's prefunctional checklists and the CA's review comments of their start-up procedures.
6. The CA develops the functional testing procedures and the subcontractors execute them under the direction, observation and approval of the CA. The CA documents the functional testing.

Specification Section 17100 provides some graphic illustrations of various management scenarios. Appropriate name substitutions can be made for the various parties involved, allowing the specifications to be applicable to other agencies or groups.

Test Engineer Scenario. There are guide specifications in the industry that use this scenario. These specifications do not. The following is a short explanation to prevent confusion. In the test engineer scenario, the contractor hires a test engineer who writes and executes the commissioning tests, etc. A person designated as the "commissioning agent" is hired by or is on the owner's staff. This commissioning agent is the line supervisor for the test engineer and acts as the owner's representative for commissioning issues. For comparison, the test engineer in the test engineer scenario, performs virtually all the tasks that the commissioning agent does under the *Model Commissioning Plan and Guide Specifications*. The commissioning agent in the test engineer scenario is analogous to the construction manager in the *Model Plan and Specs*. However, in the test engineer scenario, the commissioning agent must have considerably more commissioning experience than does the construction manager in the *Model Plan and Specs* scenario.

3. Scope

This draft of the commissioning specifications covers HVAC and automatic control systems for larger buildings. Future versions will cover electrical and other mechanical systems. However, Section 17100 describes the common requirements and processes that are applicable to all commissioned systems, not just HVAC and controls. The A/E can add systems to be commissioned without making any modifications to Section 17100, except for adding references to added systems. In general, these specifications assume that clear and complete design intent documentation was developed during the design phase. However, some language is included to handle cases when it is not.

4. Specification Sections and Responsibilities

The following describes the approach that was used to incorporate commissioning into the standard specification format.

1. The intent was to minimize redundancy and repetition whenever possible, and yet still have as many requirements for a given trade, in the trade's normal specification division and section. Specific commissioning *requirements* for a given trade are all listed in one place. However, the commissioning *procedures* to execute the requirements, many of which are common to all trades, are necessarily found in other sections. Cross references are used extensively to provide access to all procedures and requirements.

2. In all divisions with requirements that relate to commissioning, there are references to the specific commissioning requirements in other divisions.
 - a. In Division 1, Section 00800, Supplementary Conditions, there is language providing a penalty for not completing commissioning on time.
 - b. In Section 01040, Coordination, there is an introduction to commissioning, the commissioning agent and a reference to Division 17.
 - c. Section 01300 Submittals, Section 01700 Project Close-out and Section 01730 O&M Data also contain references to Division 17.
 - d. The trade sections of 15010 Mechanical General, Section 16010 Electrical General contain references to Division 17 and to the special commissioning sections within their respective divisions (15995; 16995).
3. The commissioning process details, the commissioning requirements that apply to all parties, and the specific responsibilities of the commissioning agent and non-trades, (construction and project manager) are included in a special Division 17, Commissioning.
4. A special commissioning section of Division 15, Section 15995 is used to specify common and specific commissioning requirements of all Division 15 contractors. In addition, the specific, unique responsibilities of Division 15 contractors are included in appropriate sections of Division 15 and 16 (e.g., 15950 controls, 15990 TAB).
5. Specific functional testing requirements are found in the Sections 15997 and 16997, Mechanical and Electrical Testing Requirements.
6. Specific prefunctional checklists are found in Sections 15998 and 16998.
7. Sample functional test procedures are found in Sections 15999 and 16999.

The following lists the sections included in the commissioning (Cx) guide specifications. Refer to Figure 1 for a graphical layout of the specification sections. A detailed table of contents is provided at the beginning of the major sections (15995, 17100).

00800 Supplementary Conditions Provides for a penalty if commissioning is not completed by the Functional Completion milestone.

** If the commissioning agent is hired by the owner or construction manager, 01040a applies:*

01040a Coordination Introduces commissioning and refers to Division 17.

** If the commissioning agent is hired by the general contractor, 01040b applies:*

01040b Coordination Introduces commissioning, refers to Division 17 and requires that the GC hire a qualified CA.

01300 Submittals Alerts all parties that additional detail in submittals may be required and directs to Division 17.

01700 Project Close-out Defines Substantial Completion and Functional Completion milestones, relative to commissioning.

01730 O&M Data Alerts all parties that O&M documentation may be more detailed and directs to Division 17.

15010 Mechanical General	Alerts the mechanical contractor of Cx responsibilities in 15995.
15950 Automatic Controls	Lists special requirements and alerts the controls contractor of the special requirements of the control contractor and control system in 15995.
15990 TAB	Alerts the TAB of Cx responsibilities in 15995.
15995 Mechanical Cx	Describes the Cx responsibilities of the mechanical, controls and TAB contractors and the prefunctional testing and start-up responsibilities of each. Points to 15997 for functional testing requirements.
15997 Mechanical Testing Requirements	Describes the specific functional testing requirements Division 15 equipment in the project.
15998 Mechanical Prefunctional Checklists	Provides the prefunctional checklists for use on this project, including items for Div. 15 and Div. 16.
15999 Mechanical Functional Tests-Examples	Provides example functional test procedures and formats for mechanical equipment.
16010 Electrical General	Alerts the electrical contractor of Cx responsibilities in 16995.
16995 Electrical Cx	Describes the Cx responsibilities of the electrical contractor.
16997 Electrical Testing Requirements	Describes the specific functional testing requirements for Division 16 equipment in the project.
16998 Electrical	Points to Section 15998 prefunctional checklists.
16999 Electrical Functional Tests-Examples	Provides example functional test procedures and formats for electrical equipment.
17100 Commissioning	Describes the commissioning process, responsibilities common to all parties, responsibilities of the A/E, CA, CM, PM, GC and Suppliers, focusing on the CA. The unique mechanical contractor, controls contractor, TAB and electrical contractor responsibilities are included in Div. 15 and 16.

5. Electronic Format

All sections have been included as separate files on diskette in Word 6.0 for Windows 3.1 with the following file name format. The version number refers to the specific file or section version, not the entire Guide Specification version.

[Section #. Version #] For example: file 15995.V02 is Section 15995 Version 2.

A complete listing of files is found in the overview of the entire document prior to Part I (file: all_ovr.v10).

Figure 1.

Specification Structure

Division 1

00800 Suppl. Conditions	01040 Coord.	01300 Submittals	01700 Closeout	01730 O&M Data
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Division 17

<u>Common Cx</u>	17100	<u>Responsibilities</u>
<u>Protocols</u>		* CA * A/E
		* Mfr * Owner

Division 15

15010 Mech. General	15950 Controls Misc. req'r's & points to 15995 & 17100	15990 TAB Points to 15995 & 17100	15995 Mech. Cx All Div. 15 Responsib.	15997 Mechanical Testing Required
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15998
Prefunctional
Check Lists

Division 16

**Similar to
Division 15**

15999
Sample Functional
Tests

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 00800 SUPPLEMENTARY CONDITIONS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

Frequently it is difficult enforce the requirement that the Contractor finish all their commissioning tasks prior to Substantial Completion. If this is not a practical stipulation, it then may be difficult to ever get the Contractor to finish all their commissioning responsibilities. Therefore:

To ensure that the commissioning is completed in a timely manner, and as an incentive for the Contractor to complete the commissioning work, add a new milestone and apply liquidated damages to it. The milestone is called "Functional Completion," and is defined in Section 01700. Functional Completion is a specific time period (days), after Substantial Completion, when all remaining TAB and commissioning responsibilities of the Contractor, (except for seasonal or approved deferred testing and controls training), must be completed or the stipulated liquidated damages will begin accruing.

Add language to this or other appropriate Section and that applies liquidated damages for not meeting the Functional Completion milestone.

For example:

There will be a \$ _____ per day penalty for every day that the Functional Completion milestone is exceeded.

The inclusion of commissioning in the definition for Substantial Completion and the new term Functional Completion should also be included in the General Conditions of the construction contract.

END OF GUIDE SPECIFICATION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 01040 COORDINATION COMMISSIONING AGENT AND GENERAL REQUIREMENTS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

THIS VERSION (A) OF THIS SECTION APPLIES WHEN THE COMMISSIONING AGENT IS HIRED BY GSA's CONSTRUCTION MANAGER OR DIRECTLY BY GSA
(The Commissioning Agent is the party personally directing the day-to-day commissioning activities)

Alert the Contractor that this project will be commissioned and that the Contractor will be responsible to carry out the execution of the commissioning process under the direction and approval of the Commissioning Agent.

Include the following section under PART 1 - GENERAL:

PART 1 - GENERAL

1.1. COMMISSIONING

- A. This project will have selected building systems commissioned. The equipment and systems to be commissioned are specified in Section 17100, Part 1.4. The commissioning process, which the Contractor is responsible to execute, is defined in Division 17. The commissioning process will be directed by a Commissioning Agent whose services will be provided by GSA.

SECTION 01040 Version A - 2
COORDINATION
COMMISSIONING AGENT—GENERAL REQUIREMENTS

- B. Abbreviations. The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan*. Definitions are found in Section 17100, Part 1.6.

A/E-	Architect and design engineers	FT-	Functional performance test
CA-	Commissioning agent	GC-	General contractor (prime)
CC-	Controls contractor	MC-	Mechanical contractor
CM-	Construction Manager (GSA's representative)	PC-	Prefunctional checklist
Cx-	Commissioning	PM-	Project manager (GSA, the Owner)
Cx Plan-	Commissioning Plan document	Subs-	Subcontractors to General
EC-	Electrical contractor	TAB-	Test and balance contractor

List the Commissioning Agent under the following section:

1.2 ADMINISTRATIVE / SUPERVISORY PERSONNEL

- A. Commissioning Agent: GSA will provide the services of a qualified Commissioning Agent. The responsibilities of the Commissioning Agent are defined in Division 17. The Commissioning Agent directs and approves the commissioning work.

If the Test and Balancing Contractor (TAB) will be hired by someone other than the Owner, have the TAB qualifications submitted and approved by the Owner and refer to the requirement here, per the language below. Otherwise include wording that the Owner will provide the services of a qualified TAB contractor, similar to that for the Commissioning Agent above.

- B. Test and Balance Contractor (TAB) Qualifications. The Contractor will provide the services of a qualified test and balance contractor, approved by the Owner, as specified in Section 15990.
- C. Controls Contractor and Lead Technician Qualifications. The Control contractor and the lead technician shall be approved by the Owner as specified in Section 15950.

Though not directly applicable to this section, an important reminder is made here: The Spec Writer should review any quality assurance sections, particularly 01400, and make sure that any stock language about costs of testing being the Owner's responsibility are correctly reflected consistent with the commissioning specifications.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 01040 COORDINATION COMMISSIONING AGENT AND GENERAL REQUIREMENTS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

THIS VERSION (B) OF THIS SECTION APPLIES WHEN THE COMMISSIONING AGENT IS HIRED BY THE GENERAL CONTRACTOR

(The Commissioning Agent is the party personally directing the day-to-day commissioning activities)

Alert the Contractor that this project will be commissioned and that the Contractor will be responsible to carry out the execution of the commissioning process under the approval of the Owner's Construction Manager.

Include the following section under PART 1 - GENERAL:

PART 1 - GENERAL

1.1 COMMISSIONING

- A. This project will have selected building systems commissioned. The equipment and systems to be commissioned are specified in Section 17100, Part 1.4. The commissioning process, which the Contractor is responsible to execute, is defined in Division 17. The commissioning process will be directed by a Commissioning Agent whose services will be provided by the Contractor. The commissioning will be approved by GSA's Construction Manager.

SECTION 01040 Version B - 2
COORDINATION
COMMISSIONING AGENT—GENERAL REQUIREMENTS

B. Abbreviations. The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan*. Definitions are found in Section 17100, Part 1.6.

A/E-	Architect and design engineers	FT-	Functional performance test
CA-	Commissioning agent	GC-	General contractor (prime)
CC-	Controls contractor	MC-	Mechanical contractor
CM-	Construction Manager (GSA's Representative)	PC-	Prefunctional checklist
Cx-	Commissioning	PM-	Project manager (GSA, the Owner)
Cx Plan-	Commissioning Plan document	Subs-	Subcontractors to General
EC-	Electrical contractor	TAB-	Test and balance contractor

Alert the Contractor that they will be responsible to provide the services of a qualified Commissioning Agent as follows:

1.2 ADMINISTRATIVE / SUPERVISORY PERSONNEL

A. Commissioning Agent: The Contractor will provide the services of a qualified Commissioning Agent. The responsibilities of the Commissioning Agent are defined in Division 17. The Commissioning Agent will report directly to the Owner's Construction Manager.

1. Commissioning Agent Qualifications: The Commissioning Agent will satisfy the following requirements:

The A/E should modify the requirements as appropriate for the complexity of the systems to be commissioned in this building.

List other systems that are being commissioned. If they are highly specialized (fume hoods, clean room, security, communications, etc.) state that two parties may be hired, with one acting as lead, to fulfill the expertise required.

- a. Have extensive experience in the operation and troubleshooting of HVAC systems, energy management control systems and lighting controls systems. Extensive field experience is required. A minimum of _____ full years in this type of work is required.
- b. Knowledgeable in test and balance of both air and water systems.
- c. Direct experience in monitoring and analyzing system operation using energy management control system trending or stand-alone datalogging equipment.
- d. Excellent verbal and written communication skills, highly organized and able to work with both management and trade contractors.
- e. A bachelors degree in Mechanical Engineering is highly preferred and P.E. certification is desired, however, other technical training and past commissioning and field experience will be considered.

- f. The Commissioning Agent requirements cannot be fulfilled by the combined expertise of a company, but must be part of the skill and experience set of the one individual who will be the designated Commissioning Agent, unless specifically noted above.
- g. The Commissioning Agent will be an independent contractor and not an employee of the General Contractor or any other subcontractor on this project, including the A/E.
- h. The Commissioning Agent shall have been the prime commissioning agent for commissioning at least ____ facilities of _____ sf and similar complexity in system type in the last 5 years.
- i. The Commissioning Agent will provide a detailed description of at least three commissioning projects completed recently with their personal involvement, the names and telephone numbers of the Owner's project manager and the general contractor's site superintendent.

Spec Writer: To make this section more rigorous, consider using all or parts of the commissioning agent RFP solicitation found in Part I, Appendix 1 of the *Model Commissioning Plan and Guide Specifications*.

- 2. The Contractor will submit, with the construction bid proposal, the CA's resume and qualifications to the CM, the GSA Project Manager and the A/E for approval. The Owner reserves the right to require the Contractor to submit another party for the position, in the event the first party submitted is considered unqualified for the project. Final approval will reside with the Project Manager.

Extend the duties of the CM to cover their Cx responsibilities under Administrative Personnel.

- B. Construction Manager (CM): In general, the construction management services contractor is hired by GSA to assist the government in the overall management of the project including supervising and on-site managing authority over a project's construction. The General Contractor reports to the CM. A qualified member of the CM team acts for GSA and reviews and approves the work of the Commissioning Agent and commissioning team and witnesses selected tests, as well as performing tasks specified in Division 17. This member of the CM shall have significant mechanical engineering training and expertise and have extensive field experience in troubleshooting, inspecting HVAC systems, controls and lighting systems and _____.

If the Test and Balancing Contractor (TAB) will be hired by someone other than the Owner, have the TAB qualifications submitted and approved by the Owner and refer to the requirement here, per the language below.

- C. Test and Balance Contractor (TAB) Qualifications. The Contractor will provide the services of a qualified test and balance contractor, approved by the Owner, as specified in Section 15990.

- D. Controls Contractor and Lead Technician Qualifications. The Control contractor and the lead technician shall be approved by the Owner as specified in Section 15950.

Though not directly applicable to this section, an important reminder is made here:

The Spec Writer should review any quality assurance sections, particularly 01400, and make sure that any stock language about costs of testing being the Owner's responsibility are correctly reflected consistent with the commissioning specifications.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 01300 SUBMITTALS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

Inform the Contractor that additional information is required to be submitted to the Commissioning Agent beyond normal submittals and that the Commissioning Agent will be reviewing and approving the submittals.

The following wording is to be added to the normal Submittal specification text:

1.1 SUBMITTAL REQUIREMENTS FOR COMMISSIONING

A. Normal Submittals.

1. The Commissioning Agent will receive a copy of the normal submittals for equipment to be commissioned.
2. The Commissioning Agent will review and approve normal Contractor submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the A/E reviews.

B. Data for Commissioning.

1. The Contractor will receive a written request from the Commissioning Agent requesting specific information needed about each piece of commissioned equipment or system.
2. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
3. The Commissioning Agent may request further documentation necessary for the commissioning process.
4. This data request may be made prior to normal submittals.

5. Much of this information is contained in the regular O&M manual submittals normally submitted in the project. Typically, this information is required prior to the regular formal O&M manual submittals.
- C. Contractor's responsibility for deviations in submittals from requirements of the Contract Documents is not relieved by the Commissioning Agent's review.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 01700 PROJECT CLOSE-OUT

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

Frequently it is difficult to enforce the requirement that the Contractor finish all their commissioning tasks prior to Substantial Completion. If this is not a practical stipulation, it then may be difficult to ever get the Contractor to finish all their commissioning responsibilities. Therefore:

To ensure that the commissioning is completed in a timely manner, and as an incentive for the Contractor to complete the commissioning work, add a new milestone and apply liquidated damages to it (Section 00800). The milestone in this section called "Functional Completion." Functional Completion is a specific time period (days), after Substantial Completion, when all remaining TAB and commissioning responsibilities of the Contractor, (except for seasonal or approved deferred testing and controls training), must be completed or the stipulated liquidated damages will begin accruing.

Inform the Contractor that all Commissioning in Div. 17 must be completed, except for functional testing and controls training before Substantial Completion.

Under the prerequisites to Substantial Completion section, include the following:

PREREQUISITES TO SUBSTANTIAL COMPLETION

.....
.....

The commissioning of Division 17 must be complete, except for functional testing and controls training, prior to Substantial Completion, unless approved in writing by the Owner's Project Manager.

The definition for Substantial Completion should also be added to the appropriate section of the General Conditions of the construction contract.

Inform the Contractor that all Commissioning in Div. 17 must be completed before Functional Completion, except for seasonal or approved deferred testing and controls training.

Under the prerequisites to Functional Completion section, include the following:

PREREQUISITES TO FUNCTIONAL COMPLETION

- A. All TAB work and the commissioning of Division 17 must be complete prior to Functional Completion, unless approved in writing by the Owner's Project Manager. Exceptions to this are the planned control system training performed after occupancy and any required seasonal or approved deferred testing.
 - 1. The Owner's Project Manager will determine the date of Functional Completion after reviewing the Commissioning Agent's recommendation for Functional Completion.

The definition for Functional Completion should also be added to the appropriate section of the General Conditions of the construction contract.

END OF GUIDE SPECIFICATION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 01730 OPERATIONS AND MAINTENANCE DATA

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

In an appropriate Section, alert Division 1 that they will be responsible for additional O&M documentation according to Section 17100.

- A. The commissioning process requires detailed O&M documentation. Division 1 is alerted to the O&M documentation requirements identified in this section, in Section 17100 and other referenced sections.
- B. The commissioning agent's contribution to the O&M manuals is found in Section 17100.

Following are minimum requirements for O&M manuals. This wording or other wording requiring equal or greater detail should be included and merged with the other O&M manual requirements in Division 1. Using the ASHRAE guideline: *Preparation of O&M Documentation for Building Systems*, 1993 is highly recommended.

This is not intended to be the full text for the specification section on O&M manual preparation. Additional parts dealing with submittal and review of the manuals and sections on materials and finishes manuals, etc. must still be covered.

Wording about reviews should take into account the review by the commissioning agent as described in Section 17100.

- C. The ___ GC, ___ A/E shall compile O&M manuals for every piece of equipment and building operating or electrical system with the following format.
 - 1. Quantity: _____
 - 2. Format: 8 1/2" x 11" loose leaf binders. Each binder shall be clearly labeled on the spine. Use as many as required. Do not overload binders. There shall be dividers with permanently marked tabs of card stock separating each section and sub section. Tab labels shall not be handwritten.
 - 3. There shall be a title page and table of contents in the front of each binder for each binder's contents. In each binder, there shall be a main tab for each specification section. Behind the

section number tab there shall be the equipment ID tag sub-tab for each piece of major equipment (or group, if small or numerous). These sub-tabs shall be similar to the specification number tabs but of a different color. Behind each equipment name tab shall be the following sections, in the given order, divided by a double weight colored sheet labeled with the title of the section.

- a. Contractor. The first page behind the equipment tab shall contain the name, address and telephone number of the manufacturer and installing contractor and the 24-hour number for emergency service for all equipment in this section, identified by equipment.
- b. Submittal and Product Data. This section shall include all approved submittal data, cut sheets and appropriate shop drawings. If submittal was not required for approval, descriptive product data shall be included.
- c. Operation and Maintenance Instructions. These shall be the written manufacturer's data with the model and features of this installation clearly marked and edited to omit reference to products or data not applicable to this installation. This section shall include data on the following:
 1. Installation, startup and break-in instructions
 2. All starting, normal shutdown, emergency shutdown, manual operation, seasonal changeover and normal operating procedures and data, including any special limitations.
 3. O&M and installation instructions that were shipped with the unit.
 4. Preventative maintenance and service procedures and schedules.
 5. Troubleshooting procedures.
 6. A parts list, edited to omit reference to items which do not apply to this installation.
 7. A list of any special tools required to service or maintain the equipment.
 8. Performance data, ratings and curves.
 9. Warranty, which clearly lists conditions to be maintained to keep warranty in effect and conditions that would affect the validity of the warranty.
 10. Any service contracts issued.
- d. Supplemental Data. Prepare written text and/or special drawings to provide necessary information, where manufacturer's standard printed data is not available and information is necessary for a proper understanding and operation and maintenance of equipment or systems, or where it is necessary to provide additional information to supplement data included in the manual or project documents.
- e. Control Drawings. Include the control drawings for the piece of equipment and its components, including the sequence of operation. This section will be provided by the controls contractor. The drawings will be repeated in the control contractor's O&M submittals.

The above are considered a minimum standard. Items f-i should also be considered.

- f. Specifications. This section is comprised of the component or system specification section copied and inserted complete with all addenda.

- g. System Description. This section shall include the individual equipment portion of the overall system Design Documentation Narrative, if available. It will contain simplified professionally drawn single line system diagrams on 8 ½ x 11 or 11 x 17 sheets, if the system's control drawing is not adequate.
- h. Preventive Maintenance Instructions. This section shall include condensed typewritten excerpts from the manufacturer's written instructions for weekly, monthly, quarterly, annual, etc. maintenance. This summary shall be prepared by the HVAC mechanical contractor with help from the equipment supplier. It shall be prepared for all items listed under condensed operating instructions (below), plus package, window or through the wall AC units and electric unitary heating equipment.

Below is an Option for (h.)

- h. Preventive Maintenance Instructions. This section shall include a list of the location by O&M document name and page number of the any preventative maintenance instructions applicable to this piece of equipment.

Spec writer:

The following requirement of condensed operating instructions is rarely implemented. Don't include it, unless you really want it, as the commissioning agent will not let it slip by and not be done, if it is specified. If condensed instructions are used, they should be inserted just after the Contractors' listing.

- i. Condensed Operating Instructions. This section shall include condensed instructions for start-up, shut-down, emergency operation, safety precautions, unusual features and troubleshooting suggestions. Where control is clearly covered in controls description, it is not to be duplicated here.
In addition, a copy of these instructions shall be clearly laminated and secured adjacent to the equipment where it can be easily read by operating personnel. These instructions shall be provided for boilers, furnaces, chillers, pumps, heat rejection equipment, large air handling units (greater than 10 tons), heat pump systems, control system, air compressors and dryers.
- 4. Controls and Test and Balance (TAB) O&M Manuals. The controls contractor and TAB contractor have special O&M manual preparation requirements in Section 15995 that shall be merged with those of this section.
 - 5. Architect and Design Engineers' Contributions. The architect and design engineers have special contributions to the O&M manuals as described in Section 17100.
 - 6. Commissioning Record and Testing Data. There will be a separate manual dedicated to documenting the commissioning process which will include all certifications and testing data and some repeating of O&M data. Description of this manual is found in Section 17100 and shall be prepared by the commissioning agent.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15010 MECHANICAL--GENERAL PROVISIONS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

In an appropriate section, alert Division 15 that they will be responsible for commissioning according to Section 15995, 17100 and other referenced sections.

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

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15950 AUTOMATIC CONTROLS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

In Part 1 - GENERAL, include the following text about quality assurance and commissioning and qualification of the controls manufacturer and lead installing technician.

1.1 COMMISSIONING AND QUALITY ASSURANCE

- A. Quality Assurance. Quality assurance for automatic controls systems shall be accomplished through the commissioning process consisting of submittal review of system engineering work, documented prefunctional testing and initial checkout, documented functional performance testing, operator training and O&M documentation. In addition there will be a qualification procedure for the manufacturer and lead installation technician.
- B. Related Sections. The general commissioning process procedures and requirements are given in Section 17100 with responsibilities unique to Division 15 included in Section 15995, including O&M manual documentation and training requirements. The common process requirements for initial system checkout are found in Section 17100. Specific functional testing requirements are identified in Section 15997. Specific prefunctional checklists are found in Section 15998 and sample functional test procedure formats are found in Section 15999.

1.2 QUALIFICATION OF MANUFACTURER AND LEAD INSTALLING TECHNICIAN

- A. Manufacturer and Vendor. Within 14 days after notice to proceed, the controls contractor shall submit to the GC, CM and PM a certified statement, signed by an officer of the manufacturer and vendor which includes the following: name and address of company; name, address and telephone number of the local representative; a general sales bulletin covering the full line of products manufactured; a certification that the products proposed for this contract have been in continuous and successful use for at least 1 year, not including beta testing, and general information covering the functions and characteristics of the systems proposed. In addition, provide a list of four projects which the vendor has installed that are similar in size and complexity to this contract, with the name and telephone number of the contracting officer and facility administrator, size of project, location and brief description and date of completion.

- B. Lead Installation Technician (LIT). The automatic controls will be installed under the direct and continuous supervision of a lead technician authorized by the manufacturer. Within 14 days after notice to proceed, the controls contractor shall submit the following regarding the LIT: name; address; telephone number; list of two projects of similar size and complexity to this contract which were directly supervised by the LIT; and for each project the project name, location, description, cost, name and telephone number of the contracting officer and current facility administrator and date of completion. A replacement to the LIT must be approved in writing by the Owner.
- C. Acceptance. A review of the qualifications and action upon the acceptance of the manufacturer and the LIT will be completed by the Owner. If the manufacturer, the proposed product line or the qualifications of the LIT are not in accordance with the Contract Documents or, in the opinion of the Owner, will not result in a satisfactory completed product, alternatives must be submitted for approval.

Under PART 2 - PRODUCTS, provide requirements for trend logging capabilities of the system which will aid in the commissioning process and the operation and maintenance of the building.

2.1 TREND LOGGING CAPABILITIES

- A. The control system installed shall be capable of, and set up to readily trend data with the following minimum features.
1. At least six columns of data can be viewed on the screen at once and can be graphed using a graphing program integral to the control system, with at least six parameters graphed against time on the same graph. The columnar format shall have time down the left column with columns of data to the right (one column for each parameter).
 2. Without any special or difficult conversions, this data shall be able to be storable as an ASCII delimited file in the same columnar format for use in graphing with normal commercial spreadsheet software.
 3. The trend log data is automatically downloaded at appropriate intervals onto the hard drive when space in the central computer or field cabinets becomes full, so that no data is lost. This is done without the user having to calculate the size of the trends and download frequency.
 4. Any limitations in the trending as to speed of sampling vs number of sampled points in a given trend, and the effect on actual sampling rate and simultaneousness of the sampling across parameters shall be clearly explained in writing. Programming and trending setup examples of all representative situations shall be provided.
 5. The trends shall be capable of being set up to start sampling all trended points in a given trend or group of trends at the same exact time.
 6. Specifications for standard trends shall be able to be set up by the user and be saved by a name and initiated by only recalling the name. The control contractor shall assist the operators in setting up at least six standard trends during training.
 7. Ideal, but not required, shall be the capability to graph with the control system software, one or more points against another, rather than just against time.
 8. Trending features shall be capable of easily monitoring the parameter value both on a time basis and on a change-of-state basis.

9. A key for the names and definitions of all point abbreviations (both physical and virtual) shall be provided.

Under PART 2 - PRODUCTS, require that if there is a significant difference in update time the controls contractor provide a temporary second programming and testing terminal through the entire TAB and commissioning process for text format (no graphics) to speed up the point readout updating time.

2.2 TEMPORARY PROGRAMMING AND TESTING TERMINAL

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

Require that the system be capable of making global commands, which simplifies the TAB and commissioning processes and operation of the building.

2.3 GLOBAL COMMAND CAPABILITY

- A. The system shall be capable of executing from the central control terminal, temporary or permanent global commands, such as a change in space temperature setpoint.

Under PART 2 - PRODUCTS, provide requirements for including additional control points for commissioning and better operation of the system over time.

The A/E and the design phase CA should review this list and determine which points should be included in this project (including any not listed). TAB and commissioning costs will be lower when appropriate additional points are included, and the troubleshooting process for the building operators will be improved. It is not assumed that all those points listed are needed. The value of any given point is dependent on the equipment and system, the expertise of the operating staff to make use of the points, the size of the equipment, etc. Those marked with an asterisk (*) are considered generally more valuable by the author.

2.4 COMMISSIONING AND MONITORING POINTS

- A. All control points of the central building automation system, required to automatically control the equipment specified in the Contract Documents and to execute all specified control sequences, shall be installed and be able to be monitored. To simplify TAB and commissioning of the systems and to provide better control during occupancy, the following points shall be provided as monitored points in the control system, even if they are part of equipment integral controls, or are not required

in any control sequence or intermediate calculation. Some points may be measured values or output signals, while others may be calculated or virtual points. Many points listed below may already be required to control the equipment.

Chiller System

- *Primary CHW supply flow (gpm)
- *Primary pump status
- *Percentage of load on chiller
- KW of chiller
- KW/ton (instantaneous value)
- *Secondary CHW supply flow (gpm)
- *Secondary pump status
- System load (calculation from temperature difference and gpm)
- *Secondary pump rpm or Hz
- *Return CHW temperature
- *Supply CHW temperature
- *Alarm

Cooling Tower

- *Tower status (lead, lag, etc.)
- *Fan step status, current or speed
- Damper status
- Spray pump status
- *Leaving water temperature
- *Entering water temperature
- *Bypass valve position
- *Condenser pump status
- Condenser pump current
- Sump level
- *Alarm (low water, fan vibration)

Boiler System

- Primary HW supply flow (gpm), if no secondary
- *Primary pump status
- *Lead/lag status of boiler
- Firing rate status (high/low)
- *Primary HW return temperature
- *Primary HW supply temperature
- Secondary HW supply flow (gpm)
- Secondary HW return temperature
- System load (calculation from temperature difference and gpm)
- *Secondary pump rpm or Hz
- *Boiler in alarm
- *3 way mixing valve position

Air Handler Units (AHUs) of 100 tons capacity or greater

Supply Fan

- *Discharge static pressure

- *Flow at discharge (cfm)
- *Supply fan rpm or Hz if on VFD, else vane or vane-axial blade position or current
- *Mixed air temperature (unless a tight packaged unit where a good mixed air reading is difficult)
- *Cooling coil leaving air temperature
- *Heating coil leaving air temperature
- *Supply air temperature
- *Return air temperature
- *Outside air temperature
- *Mixed air damper position
- *Return air damper position
- *Exhaust or relief damper position, optional
- *Outside air dampers position (min. damper and economizing damper)
- Leaving RH
- Inside RH
- Outside RH
- *Cooling coil valve position
- *Heating coil valve position
- Coil CHW supply temperature
- *Coil CHW return temperature
- Coil HW supply temperature
- *Coil HW return temperature
- *Duct static pressure

Return Fan/Relief Fan (associated with AHUs of 100 tons capacity or greater)

- Flow near inlet
- *Return fan rpm or Hz, if on VFD or current
- *Relief damper and return damper position, optional
- Flow of minimum outside air (OSA), if varies with VAV boxes
- CO₂ sensor for OSA control
- *Building static, if control point

Air Terminal Units

- *Flow (primary)
- *Percentage of design flow cooling
- *Percentage of design flow heating
- *Reheat fan status
- Supply air temperature to zone
- *Zone space temperature
- *Reheat valve position

The Spec Writer should specify all additional monitoring points desired for all systems in the project.

Air Handler Units (AHUs) of less than 100 tons capacity
Packaged Rooftop Units (RTUs) greater than or equal to 100 tons capacity

Packaged Rooftop Units (RTUs) less than 100 tons capacity
Computer Room AC Units
Spot AC Units (greater than 1.5 ton)
Spot Unit Heaters (greater than 1.5 ton)
Elevator Shaft Fans
Stairwell Fans
Restroom Central Exhaust Fans
Garage Exhaust Fans
Emergency Generator
Domestic Hot Water Systems
(boiler, HW heaters, leaving temp, recirc pumps)
Domestic Water Booster Pump
Sewage Ejector
Fire Alarm Interface
Lighting and Controls

2.5 TEST PORTS

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

2.6 GAGES

- A. The controls contractor shall provide gages in the following locations, even if included as a sensor and monitored point in the control system:
1. Pressure gages on both sides of all pumps greater than 1 hp.
 2. Mercury thermometers in the return and supply of all primary thermal plant equipment (chillers, cooling towers, boilers, converters, etc.).

In PART 3 - EXECUTION (or in Part 1), include a reference to the submittal requirements related to commissioning in other sections and to the submission of qualification data.

3.1 SUBMITTALS

- A. The controls contractor shall submit the manufacturer and lead installation technician data according to Part 1 of this section. Upon acceptance, proceed with shop drawings and other submittal data.
- B. The controls contractor shall follow the other submittal requirements in Section 15995, 01300 and 17100.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15990 TEST, ADJUST AND BALANCE

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

In an appropriate section, alert TAB that they will be responsible for commissioning according to Section 15995, 17100 and other sections referenced in 17100.

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

If the Test and Balancing Contractor (TAB) will be hired by someone other than the Owner, have the TAB qualifications submitted and approved by the Owner.

1. QUALIFICATIONS OF TAB CONTRACTOR AND LEAD TECHNICIAN

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

The A/E should modify the TAB requirements to be appropriate for the complexity of the systems to be installed in this building.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15995 MECHANICAL SYSTEMS COMMISSIONING

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choices that apply. Delete all direction boxes.

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PART 1 - GENERAL

1.1 DESCRIPTION

- A. The purpose of this section is to specify Division 15 responsibilities in the commissioning process.
- B. The systems to be commissioned are listed in Section 17100.1.7.
- C. Commissioning requires the participation of Division 15 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Division 17. Division 15 shall be familiar with all parts of Division 17 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 RESPONSIBILITIES

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

Construction and Acceptance Phases

- 1. Include and itemize the cost of commissioning in the contract price.
- 2. In each purchase order or subcontract written, include requirements for submittal data, commissioning documentation, O&M data and training.
- 3. Attend a commissioning scoping meeting and other meetings necessary to facilitate the Cx process.
- 4. Contractors shall provide the CA with normal cut sheets and shop drawing submittals of commissioned equipment.
- 5. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of start-up and functional testing procedures.
 - a. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation, start-up and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
 - b. The Commissioning Agent may request further documentation necessary for the commissioning process.
 - c. This data request may be made prior to normal submittals.

The above information about special commissioning submittals is repeated in Section 01300. Maintain consistency.

- 6. Provide a copy of the O&M manuals and submittals of commissioned equipment, through normal channels, to the CA for review and approval.

7. Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
8. Provide limited assistance to the CA in preparing the specific functional performance test procedures as specified in Section 15997. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
9. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the prefunctional checklists from the CA for all commissioned equipment. Submit to CA for review and approval prior to startup. Refer to Section 17100 for further details on start-up plan preparation.
10. During the startup and initial checkout process, execute the mechanical-related portions of the prefunctional checklists for all commissioned equipment.
11. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
12. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
13. Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
14. Perform functional performance testing under the direction of the CA for specified equipment in Section 15997 and 17100. Assist the CA in interpreting the monitoring data, as necessary.
15. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, CM and A/E and retest the equipment.
16. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
17. Prepare red-line as-built drawings for all drawings and final as-builds for contractor-generated coordination drawings.
18. Provide training of the Owner's operating personnel as specified.
19. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

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

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

1. Provide startup for all HVAC equipment, except for the building automation control system.
2. Assist and cooperate with the TAB contractor and CA by:
 - a. Putting all HVAC equipment and systems into operation and continuing the operation during each working day of TAB and commissioning, as required.
 - b. Including cost of sheaves and belts that may be required by TAB.
 - c. Providing test holes in ducts and plenums where directed by TAB to allow air measurements and air balancing. Providing an approved plug.
 - d. Providing temperature and pressure taps according to the Construction Documents for TAB and commissioning testing.
3. Install a P/T plug at each water sensor which is an input point to the control system.
4. List and clearly identify on the as-built drawings the locations of all air-flow stations.
5. Prepare a preliminary schedule for Division 15 pipe and duct system testing, flushing and cleaning, equipment start-up and TAB start and completion for use by the CA. Update the schedule as appropriate.
6. Notify the CM or CA depending on protocol, when pipe and duct system testing, flushing, cleaning, startup of each piece of equipment and TAB will occur. Be responsible to notify the CM or CA, ahead of time, when commissioning activities not yet performed or not yet scheduled will delay construction. Be proactive in seeing that commissioning processes are executed and that the CA has the scheduling information needed to efficiently execute the commissioning process.

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

1. Sequences of Operation Submittals. The Controls Contractor's submittals of control drawings shall include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications. They shall include:
 - a. An overview narrative of the system (1 or 2 paragraphs) generally describing its purpose, components and function.
 - b. All interactions and interlocks with other systems.
 - c. Detailed delineation of control between any packaged controls and the building automation system, listing what points the BAS monitors only and what BAS points are control points and are adjustable.
 - d. Written sequences of control for packaged controlled equipment. (Equipment manufacturers' stock sequences may be included, but will generally require additional narrative).
 - e. Start-up sequences.
 - f. Warm-up mode sequences.
 - g. Normal operating mode sequences.

- h. Unoccupied mode sequences.
- i. Shutdown sequences.
- j. Capacity control sequences and equipment staging.
- k. Temperature and pressure control: setbacks, setups, resets, etc.
- l. Detailed sequences for all control strategies, e.g., economizer control, optimum start/stop, staging, optimization, demand limiting, etc.
- m. Effects of power or equipment failure with all standby component functions.
- n. Sequences for all alarms and emergency shut downs.
- o. Seasonal operational differences and recommendations.
- p. Initial and recommended values for all adjustable settings, setpoints and parameters that are typically set or adjusted by operating staff; and any other control settings or fixed values, delays, etc. that will be useful during testing and operating the equipment.
- q. Schedules, if known.
- r. All sequences shall be written in small statements, each with a number for reference. For a given system, numbers will not repeat for different sequence sections, unless the sections are numbered.

2. Control Drawings Submittal

- a. The control drawings shall have a key to all abbreviations.
- b. The control drawings shall contain graphic schematic depictions of the systems and each component.
- c. The schematics will include the system and component layout of any equipment that the control system monitors, enables or controls, even if the equipment is primarily controlled by packaged or integral controls.
- d. Provide a full points list with at least the following included for each point:
 - 1) Controlled system
 - 2) Point abbreviation
 - 3) Point description
 - 4) Display unit
 - 5) Control point or setpoint (Yes / No)
 - 6) Monitoring point (Yes / No)
 - 7) Intermediate point (Yes / No)
 - 8) Calculated point (Yes / No)

Key:

Point Description: DB temp, airflow, etc.

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

Intermediate Point: Point whose value is used to make a calculation which then controls equipment (space temperatures that are averaged to a virtual point to control reset).

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

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

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

- 3. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal.

4. Assist and cooperate with the TAB contractor in the following manner:
 - a. Meet with the TAB contractor prior to beginning TAB and review the TAB plan to determine the capabilities of the control system toward completing TAB. Provide the TAB any needed unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).
 - b. For a given area, have all required prefunctional checklists, calibrations, startup and selected functional tests of the system completed and approved by the CA prior to TAB.
 - c. Provide a qualified technician to operate the controls to assist the TAB contractor in performing TAB, or provide sufficient training for TAB to operate the system without assistance.
5. Assist and cooperate with the CA in the following manner:
 - a. Execute the functional testing of the controls system as specified for the controls contractor in Section 15997 and 16997.
 - b. Assist in the functional testing of all equipment specified in Section 15997 and 16997.
 - c. Execute all control system trend logs specified in Section 15997 and 16997.
6. The controls contractor shall prepare a written plan indicating in a step-by-step manner, the procedures that will be followed to test, checkout and adjust the control system prior to functional performance testing, according to the process in Section 17100. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:
 - a. System name.
 - b. List of devices.
 - c. Step-by-step procedures for testing each controller after installation, including:
 - 1) Process of verifying proper hardware and wiring installation.
 - 2) Process of downloading programs to local controllers and verifying that they are addressed correctly.
 - 3) Process of performing operational checks of each controlled component.
 - 4) Plan and process for calibrating valve and damper actuators and all sensors.
 - 5) A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.
 - d. A copy of the log and field checkout sheets that will document the process. This log must include a place for initial and final read values during calibration of each point and clearly indicate when a sensor or controller has "passed" and is operating within the contract parameters.
 - e. A description of the instrumentation required for testing.
 - f. Indicate what tests on what systems should be completed prior to TAB using the control system for TAB work. Coordinate with the CA and TAB contractor for this determination.
7. Provide a signed and dated certification to the CA and CM upon completion of the checkout of each controlled device, equipment and system prior to functional testing for each piece of equipment or system, that all system programming is complete as to all respects of the Contract Documents, except functional testing requirements.
8. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control and virtual points as specified in Section 15950.

9. List and clearly identify on the as-built duct and piping drawings the locations of all static and differential pressure sensors (air, water and building pressure).
- D. TAB Contractor. The duties of the TAB contractor, in addition to those listed in (A) are:
1. Six weeks prior to starting TAB, submit to the CM the qualifications of the site technician for the project, including the name of the contractors and facility managers of recent projects the technician on which was lead. The Owner will approve the site technician's qualifications for this project.
 2. Submit the outline of the TAB plan and approach for each system and component to the CA, CM and the controls contractor six weeks prior to starting the TAB. This plan will be developed after the TAB has some familiarity with the control system.
 3. The submitted plan will include:
 - a. Certification that the TAB contractor has reviewed the construction documents and the systems with the design engineers and contractors to sufficiently understand the design intent for each system.
 - b. An explanation of the intended use of the building control system. The controls contractor will comment on feasibility of the plan.
 - c. All field checkout sheets and logs to be used that list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each.
 - d. Discussion of what notations and markings will be made on the duct and piping drawings during the process.
 - e. Final test report forms to be used.
 - f. Detailed step-by-step procedures for TAB work for each system and issue: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions, etc. Criteria for using air flow straighteners or relocating flow stations and sensors will be discussed. Provide the analogous explanations for the water side.
 - g. List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and a description of specific test procedures, parameters, formulas to be used.
 - h. Details of how *total* flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood readings of all terminals, supply (SA) and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.).
 - i. The identification and types of measurement instruments to be used and their most recent calibration date.
 - j. Specific procedures that will ensure that both air and water side are operating at the lowest possible pressures and provide methods to verify this.
 - k. Confirmation that TAB understands the outside air ventilation criteria under all conditions.
 - l. Details of whether and how minimum outside air cfm will be verified and set, and for what level (total building, zone, etc.).
 - m. Details of how building static and exhaust fan / relief damper capacity will be checked.
 - n. Proposed selection points for sound measurements and sound measurement methods.
 - o. Details of methods for making any specified coil or other system plant capacity measurements.
 - p. Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later.

- q. Details regarding specified deferred or seasonal TAB work.
 - r. Details of any specified false loading of systems to complete TAB work.
 - s. Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.
 - t. Details of any required interstitial cavity differential pressure measurements and calculations.
 - u. Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency).
 - v. Plan for formal progress reports (scope and frequency).
 - w. Plan for formal deficiency reports (scope, frequency and distribution).
- 4. A running log of events and issues shall be kept by the TAB field technicians. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests to the CA and CM at least twice a week.
 - 5. Communicate in writing to the controls contractor all setpoint and parameter changes made or problems and discrepancies identified during TAB which affect the control system setup and operation.
 - 6. Provide a draft TAB report within two weeks of completion. A copy will be provided to the CA. The report will contain a full explanation of the methodology, assumptions and the results in a clear format with designations of all uncommon abbreviations and column headings. The report should follow the latest and most rigorous reporting recommendations by AABC, NEBB or ASHRAE Standard 111.
 - 7. Provide the CA with any requested data, gathered, but not shown on the draft reports.
 - 8. Provide a final TAB report for the CA with details, as in the draft.
 - 9. Conduct functional performance tests and checks on the original TAB as specified for TAB in Section 15997.

E. Mechanical Designer. Refer to Section 17100 for the responsibilities of the mechanical designer.

1.3 RELATED WORK

- A. Refer to Section 17100, Part 1.5 for a listing of all sections where commissioning requirements are found.
- B. Refer to Section 17100 Part 1.4 for systems to be commissioned and section 17100 Part 1.6 and 15997 for functional testing requirements.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

- A. Division 15 shall provide all test equipment necessary to fulfill the testing requirements of this Division.
- B. Refer to Section 17100 Part 2.1 for additional Division 15 requirements.

PART 3 - EXECUTION

3.1 SUBMITTALS

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

3.2 STARTUP

- A. The HVAC mechanical and controls contractors shall follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 17100. Division 15 has start-up responsibility and is required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.
- B. Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion, does not relieve the Contractor from fully completing the system, including all prefunctional checklists as soon as possible.

3.3 TAB

- A. Refer to the TAB responsibilities in Part 1.2 above.

3.4 FUNCTIONAL PERFORMANCE TESTS

- A. Refer to Section 17100 Part 1.4 for a list of systems to be commissioned and to Part 3.6 for a description of the process and to Section 15997 for specific details on the required functional performance tests.

3.5 TESTING DOCUMENTATION, NON-CONFORMANCE AND APPROVALS

- A. Refer to Section 17100 Part 3.4 for specific details on non-conformance issues relating to prefunctional checklists and tests.
- B. Refer to Section 17100 Part 3.7 for issues relating to functional performance tests.

3.6 OPERATION AND MAINTENANCE (O&M) MANUALS

The following O&M documentation requirements assume that the general contractor is compiling the O&M manuals, with all Subs compiling their own sections, including some submissions for the A/E and CA.

These requirements may need to be merged and edited to follow the protocols and scope of the current agency or project. However, the comprehensiveness and accessibility described herein shall be maintained.

- A. The following O&M manual requirements do not replace O&M manual documentation requirements elsewhere in these specifications.
- B. Division 15 shall compile and prepare documentation for all equipment and systems covered in Division 15 and deliver this documentation to the GC for inclusion in the O&M manuals, according to this section and Section 01730, prior to the training of owner personnel.
- C. The CA shall receive a copy of the O&M manuals for review.
- D. Special Control System O&M Manual Requirements. In addition to documentation that may be specified elsewhere, the controls contractor shall compile and organize at minimum the following data on the control system in labeled 3-ring binders with indexed tabs.
 - 1. Three copies of the controls training manuals in a separate manual from the O&M manuals.
 - 2. Operation and Maintenance Manuals containing:
 - a. Specific instructions on how to perform and apply all functions, features, modes, etc. mentioned in the controls training sections of this specification and other features of this system. These instructions shall be step-by-step. Indexes and clear tables of contents shall be included. The detailed technical manual for programming and customizing control loops and algorithms shall be included.
 - b. Full as-built set of control drawings (refer to Submittal section above for details).
 - c. Full as-built sequence of operations for each piece of equipment.
 - d. Full points list. In addition to the updated points list required in the original submittals (Part 1 of this section), a listing of all rooms shall be provided with the following information for each room:
 - 1) Floor
 - 2) Room number
 - 3) Room name
 - 4) Air handler unit ID
 - 5) Reference drawing number
 - 6) Air terminal unit tag ID
 - 7) Heating and/or cooling valve tag ID
 - 8) Minimum cfm
 - 9) Maximum cfm
 - e. Full print out of all schedules and set points after testing and acceptance of the system.

- f. Full as-built print out of software program.
 - g. Electronic copy on disk of the entire program for this facility.
 - h. Marking of all system sensors and thermostats on the as-built floor plan and mechanical drawings with their control system designations.
 - i. Maintenance instructions, including sensor calibration requirements and methods by sensor type, etc.
 - j. Control equipment component submittals, parts lists, etc.
 - k. Warranty requirements.
 - l. Copies of all checkout tests and calibrations performed by the Contractor (not commissioning tests).
3. The manual shall be organized and subdivided with permanently labeled tabs for each of the following data in the given order:
 - a. Sequences of operation
 - b. Control drawings
 - c. Points lists
 - d. Controller / module data
 - e. Thermostats and timers
 - f. Sensors and DP switches
 - g. Valves and valve actuators
 - h. Dampers and damper actuators
 - i. Program setups (software program printouts)
 4. Field checkout sheets and trend logs should be provided to the CA for inclusion in the Commissioning Record Book.
- E. Special TAB Documentation Requirements. The TAB will compile and submit the following with other documentation that may be specified elsewhere in the *Specifications*.
1. Final report containing an explanation of the methodology, assumptions, test conditions and the results in a clear format with designations of all uncommon abbreviations and column headings.
 2. The TAB shall mark on the drawings where all traverse and other critical measurements were taken and cross reference the location in the TAB report.
- F. Review and Approvals. Review of the commissioning related sections of the O&M manuals shall be made by the A/E and by the CA. Refer to Section 17100, Part 3.8 for details.

3.7. TRAINING OF OWNER PERSONNEL

- A. The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 17100 for additional details.
- B. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 17100 for additional details.
- C. Mechanical Contractor. The mechanical contractor shall have the following training responsibilities:

1. Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 17100, Part 3.9.
2. Provide designated Owner personnel with comprehensive orientation and training in the understanding of the systems and the operation and maintenance of each piece of HVAC equipment including, but not limited to, pumps, boilers, furnaces, chillers, heat rejection equipment, air conditioning units, air handling units, fans, terminal units, controls and water treatment systems, etc.
3. Training shall normally start with classroom sessions followed by hands-on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment are required. More than one party may be required to execute the training.
6. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
7. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
8. Training shall include:
 - a. Use of the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - b. A review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shut-down, seasonal changeover and any emergency procedures.
 - c. Discussion of relevant health and safety issues and concerns.
 - d. Discussion of warranties and guarantees.
 - e. Common troubleshooting problems and solutions.
 - f. Explanatory information included in the O&M manuals and the location of all plans and manuals in the facility.
 - g. Discussion of any peculiarities of equipment installation or operation.
 - h. The format and training agenda in *The HVAC Commissioning Process, ASHRAE Guideline 1-1989R*, 1996 is recommended.
 - i. Classroom sessions shall include the use of overhead projections, slides, video/audio-taped material as might be appropriate.
9. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and preventative maintenance for all pieces of equipment.
10. The mechanical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not *controlled* by the central control system.

11. Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.
12. Duration of Training. The mechanical contractor shall provide training on each piece of equipment according to the following schedule.

<u>Hours</u>	<u>System</u>
_____	Chillers and System
_____	Cooling Towers
_____	Boilers and System
_____	Piping Systems
_____	Chemical Treatment
_____	Air Compressors and dryers
_____	Air Handler Units
_____	Variable Speed Drives
_____	Supplementary Supply Fans
_____	Return Fan/Relief Fan
_____	Air Terminal Units
_____	Air Handler Units
_____	Packaged Rooftop Units
_____	Packaged Rooftop Units
_____	Computer Room AC Units
_____	Split System AC or Heat Pumps
_____	Spot AC Units
_____	Spot Unit Heaters
_____	Elevator Shaft Fans
_____	Stairwell Fans
_____	Specialty Exhaust Fans
_____	Restroom Central Exhaust Fans
_____	Garage Exhaust Fans
_____	Emergency Generator
_____	Service Hot Water Heaters
_____	Domestic Water Booster Pump
_____	Sewage Ejector
_____	Fire Protection System
_____	Fire Sprinklers
_____	Irrigation
_____	Fountain pumping

<p>The Spec Writer should list and specify training for all equipment not listed here.</p>
--

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

1. Provide the CA with a training plan four weeks before the planned training according to the outline described in Section 17100, Part 3.9.
2. The controls contractor shall provide designated Owner personnel training on the control system in this facility. The intent is to clearly and completely instruct the Owner on all the capabilities of the control system.
3. Training manuals. The standard operating manual for the system and any special training manuals will be provided for each trainee, with three extra copies left for the O&M manuals. In addition, copies of the system technical manual will be demonstrated during training and three copies submitted with the O&M manuals. Manuals shall include detailed description of the subject matter for each session. The manuals will cover all control sequences and have a definitions section that fully describes all relevant words used in the manuals *and* in all software displays. Manuals will be approved by the CA. Copies of audiovisuals shall be delivered to the Owner.
4. The trainings will be tailored to the needs and skill-level of the trainees.
5. The trainers will be knowledgeable on the system and its use in buildings. For the on-site sessions, the most qualified trainer(s) will be used. The Owner shall approve the instructor prior to scheduling the training.
6. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
7. The controls contractor shall attend sessions other than the controls training, as requested, to discuss the interaction of the controls system as it relates to the equipment being discussed.
8. There shall be three training sessions:
 - a. Training I. Control System. The first training shall consist of ____ hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system.
 - b. Training II. Building Systems. The second session shall be held on-site for a period of ____ hours of actual hands-on training after the completion of system commissioning. The session shall include instruction on:
 - 1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls and any interface with security and communication systems.
 - 2) Security levels, alarms, system start-up, shut-down, power outage and restart routines, changing setpoints and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and set points that if changed will adversely affect energy consumption, energy accounting, procedures for obtaining vendor assistance, etc.
 - 3) All trending and monitoring features (values, change of state, totalization, etc.), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees will actually set-up trends in the presence of the trainer.
 - 4) Every screen shall be completely discussed, allowing time for questions.

- 5) Use of keypad or plug-in laptop computer at the zone level.
- 6) Use of remote access to the system via phone lines or networks.
- 7) Setting up and changing an air terminal unit controller.

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

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

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

3.8. DEFERRED TESTING

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

3.9 WRITTEN WORK PRODUCTS

- A. Written work products of Contractors will consist of the start-up and initial checkout plan described in Section 17100 and the filled out start-up, initial checkout and prefunctional checklists.

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15997 MECHANICAL TESTING REQUIREMENTS

Spec writer:

The following guide specifications are intended to be reviewed and modified to meet the specific commissioning needs and requirements for the current project and systems. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

Spec Writer: A/E and design phase CA should:

1. Review the functional test requirements and add or change requirements, as necessary, for the current project. Pay particular attention to smaller equipment (small AHU, RTUs etc.) which will not warrant the same rigor as larger units portrayed here currently. Delete requirements for equipment not existing in the current project.
2. Make sure that every piece of mechanical equipment or system has a unique test requirement or is listed as a component of a system with testing requirements given. Use the format of this section for new test requirements.
3. Include intersystem test requirements where significant interactions or interlocks exist between systems.
4. Consider the adequacy of the Guide Specification Acceptance Criteria and add detail where necessary.

PART 1 - GENERAL

1.1. INCLUDED SYSTEMS AND EQUIPMENT

- A. The following is a list of the equipment and system test requirements included in this section:
1. Cooling tower
 2. Chiller system
 3. Air handler system
 4. Terminal unit
 5. Packaged DX air conditioning or heat pump
 6. Boiler system
 7. Exhaust fans
 8. Service hot water system
 9. Building automation system
 10. Test and balance (TAB) work
 11. Indoor air quality (IAQ)

1.2 DESCRIPTION

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

1. The contractors responsible to execute the tests, under the direction of the CA.
2. A list of the integral components being tested.
3. Prefunctional checklists associated with the components.
4. Functions and modes to be tested.
5. Required conditions of the test for each mode.
6. Special procedures.
7. Required methods of testing.
8. Required monitoring.
9. Acceptance criteria.
10. Sampling strategies allowed.

1.3 PREREQUISITES

The following applicable generic prerequisite checklist items are required to be listed on each written functional test form and be completed and checked off by CA prior to functional testing.

- ☐ All related equipment has been started up and start-up reports and prefunctional checklists submitted and approved ready for functional testing:
- ☐ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal

Date

- ☐ Piping system flushing complete and required report approved.
- ☐ Water treatment system complete and operational.
- ☐ Vibration control report approved (if required).
- ☐ Test and balance (TAB) complete and approved for the hydronic system.
- ☐ All A/E punchlist items for this equipment corrected.
- ☐ These functional test procedures reviewed and approved by installing contractor.
- ☐ Safeties and operating ranges reviewed by the CA.
- ☐ Test requirements and sequences of operation attached.
- ☐ Schedules and setpoints attached.
- ☐ False loading equipment, system and procedures ready.
- ☐ Crankcase heaters have been on long enough for immediate startup.
- ☐ Sufficient clearance around equipment for servicing.
- ☐ Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
- ☐ Other miscellaneous checks of the prefunctional checklist and start-up reports completed successfully.

1.4 MONITORING

- a. Monitoring is a method of testing as a stand-alone method or to augment manual testing.
- b. All points listed in the required monitoring section of the test requirements which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the

CA using dataloggers. At the option of the CA, some control system monitoring may be replaced with datalogger monitoring. At the CA's request, the controls contractor shall trend up to 20% more points than listed herein at no extra charge.

- c. Hard copies of monitored data must be in columnar format with time down the left column and at least 5 columns of point values on the same page.
- d. Graphical output is desirable, and will be required for all output, if the system can produce it.

PART 2 - PRODUCTS

-- NOT APPLICABLE --

PART 3 - EXECUTION

1. COOLING TOWER

The cooling tower can be tested integrally with the chiller testing.

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls
2. HVAC mechanical contractor or vendor: assist in testing sequences

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Condenser water pump	PC-_____
2. Cooling tower and components	PC-_____
3. Condenser water piping system	PC-_____
4. Fan VFD	PC-_____

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Cooling season modes of operation.	Both	Cooling
3. Heating season modes of operation.	Both	Heating
4. Lead/lag staging of towers, including testing each tower as lead tower. Staging of fans, spray pumps, condenser pumps, CDWT reset, time delays.	Both, except ²	
5. Bypass valve operation and ability of CT to maintain entering CDW temperature.	Either	
6. Sump heater and freeze protection operation.	Either	Heating
7. All alarms: vibration, fan failure, high water, low water.	Manual	
8. Verify approach temperature with manuf. specs, optional.	Either	
9. VFD operation: modulation to low limit, controlling PID, proportional band of speed vs control parameter, verification of program settings, alarms.	Both	
10. Capacity test, optional.	Manual	Clg. Des.
11. Sensor and actuator calibration checks: See Chiller requirements.	Manual	
12. Verify schedules and setpoints to be reasonable and appropriate.		

¹Cooling season, Heating season or Both. "Design" means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that testing can be executed during any season, if condition simulation is appropriate.

²Monitoring testing each tower as lead tower is not necessary.

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

1. Tests to be made with chiller in automatic mode.
2. False load chiller, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each CT:					
CDEWT	5	Wed. - Sat	Y	Y	1, 2, 4, 9
CDLWT	5	Wed. - Sat	Y	Y	1, 2, 4, 8, 9
OSAT-DB	5	Wed. - Sat	Y	Y	1, 2, 4, 8, 9
OSAT-WB (optional)	5	Wed. - Sat	Y	Y	8
Fan motor speed, stage or current	5	Wed. - Sat	Y	Y	4, 9
CDW pump status or current	5	Wed. - Sat	Y	Y	1, 2, 4, 9
Each chiller status or current	5	Wed. - Sat	Y	Y	1, 2, 4, 9

Remarks:

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

- 1-12. For the conditions, sequences and modes tested, the cooling tower(s), integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
5. Cooling tower should be able to maintain the current specified setpoint for entering condenser water to within +/- 2F, when outside conditions do not restrict this thermodynamically.

H. Sampling Strategy for Identical Units (xx% Sampling —yy% Failure Rule is defined in Section 17100, Part 3.6)

1. No sampling, test all.

END OF REQUIREMENTS FOR COOLING TOWER TEST

2. CHILLER

The cooling tower can be tested integrally with the chiller testing. The cooling tower test requirements are listed elsewhere.

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls
2. HVAC mechanical contractor or vendor: assist in testing sequences

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

C. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Chiller	PC-_____
2. Primary CHW supply pumps	PC-_____
3. Chilled water piping system	PC-_____
4. Secondary CHW supply pumps	PC-_____
5. VFD on secondary pumps	PC-_____

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated. A full cycle from no load to full load and then to no load and compressors off shall be demonstrated.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. <u>Primary Side.</u> Lead/lag staging of chillers, optimization, capacity modulation (loading and unloading), heat reclaim, and primary CHW supply pumps, all relating to maintaining CDW and CHW temperatures.	Both	Cooling
3. <u>Secondary Side.</u> Secondary CWH supply pump staging, bypass valve operation, if no VFD and CHWT reset. VFD operation: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, alarms, verification of program settings, etc.	Both	Cooling
4. All alarms: high and low pressure, low oil, etc.	Manual	
5. Test each possible lead chiller as lead chiller, and each pump as lead pump, including standby pumps.	Manual	
6. kW/ton and APLV efficiency test, optional	Manual	Cooling
7. Capacity test, optional	Manual	Cooling Design

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required Seasonal Test¹</u>
8. Sensor and actuator calibration checks on: ECDWT, CHWST, pressure sensor controlling pump speed, 3-way valve, and other random checks (EMS readout against handheld calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure setpoint, with a test gage)	Manual	
9. Verify schedules and setpoints to be reasonable and appropriate		

¹Cooling season, Heating season or Both. "Design" means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

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

1. Test with cooling tower in automatic mode.
2. False load chiller, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each chiller and pump:					
Chiller current	5	5 days incl. weekend	Y	Y	1-3
ECDWT	5	5 days incl. weekend	Y	Y	1-3
LCDWT	5	5 days incl. weekend	Y	Y	1-3
CDW pump current or status	5	5 days incl. weekend	Y	Y	1-3
CHWST	5	5 days incl. weekend	Y	Y	1, 3
CHWRT	5	5 days incl. weekend	Y	Y	1, 3
OSAT-DB	5	5 days incl. weekend	Y	Y	1-3
CHWS primary pump current or status	5	5 days incl. weekend	Y	Y	1, 2
CHWS secondary pump speed, if variable	5	5 days incl. weekend	Y	Y	1, 3
CHWS secondary pump flow rate	5	5 days incl. weekend	Y	Y	1, 3
CHWS secondary pump speed controlling parameter value	5	5 days incl. weekend	Y	Y	1, 3

Remarks:

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

- 1-9. For the conditions, sequences and modes tested, the chillers, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
 2. Chiller shall maintain the chilled water supply setpoint to within +/- 1.0F of setpoint deadband without excessive hunting.
 9. Pumping system and controls shall maintain the current desired pressure setpoint to within an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.
- H. Sampling Strategy for Identical Units (xx% Sampling — yy% Failure Rule is defined in Section 17100, Part 3.6)
1. No sampling, test all.

END OF REQUIREMENTS FOR CHILLER TEST

3. AIR HANDLER UNITS (AHU)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. AHU and components (fans, coils, valves, ducts, VFD)
2. Heat recovery coil, humidifier or evaporative cooling sections

PC-_____

PC-_____

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both ³	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Mixed & supply air, & reset temperature control functions.	Both	
3. Economizer functions.	Both	Cooling
4. SF, RF and exhaust fan interlocks.	Either	
5. No CCV flow when there is HCV flow.	Both	
6. CCV & HCV modulation & positive shutoff (no leak-thru).	Manual	
7. Duct static pressure (SP) control.	Both	
8. Return or exhaust fan tracking and building SP.	Monitoring	
9. VFD (or inlet vanes) operation on SF and RF: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, constancy of static pressure, verification of program settings, alarms, etc.	Both	²
10. Damper interlocks and correct modulation in all modes, including smoke and fire dampers.	Manual	
11. Temperature difference across HC & CC per specifications.	Manual	
12. Verification of minimum OSA control through varying VAV box positions.	Either	²
13. Heating and cooling coils freeze protection.	Manual	²
14. Branch duct control damper control.	Manual	
15. Night low limit, morning warmup cycle.	Either	
16. Heat recovery operation.	Monitoring	
17. Verify TAB reported SF cfm with control system reading.	Manual	²
18. All alarms (low limits, high static, etc.).	Manual	
19. Heating and cooling coil capacity test, optional.	Manual	Design

Function / Mode	Test Method Manual, Monitoring, Either or Both ³	Required Seasonal Test ¹
20. Sensor and actuator calibration checks: on duct static pressure sensor on SAT, MAT, OSAT, OSA & RA damper and valve positions, SF cfm reading with TAB, and other random checks (EMS readout against hand-held calibrated instrument or observation must be within specified tolerances)	Manual	
21. Verify schedules and setpoints to be reasonable and appropriate		

¹Cooling season, Heating season or Both. "Design" means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

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

1. Reduced Testing for Smaller Units. For standard application AHU's less than 15 tons, the following modifications to the testing requirements apply: 1) either Manual or Monitoring will satisfy the verification requirement—where Both is listed, choose one. 2) Testing Modes 6, 8, 11, 13 and 16 is not required.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each AHU being tested:					
RAT	5	5 days incl. weekend	Y	Y	1-3, 5
SAT	5	5 days incl. weekend	Y	Y	1-3, 5
CC LAT (optional)	5	5 days incl. weekend	Y	Y	1-3, 5
HC LAT (optional)	5	5 days incl. weekend	Y	Y	1-3, 5
MAT	5	5 days incl. weekend	Y	Y	1, 3
Indoor WB or enthalpy, if enthalpy economizer	5	5 days incl. weekend	Y	Y	1, 3
SF speed, if variable, else status	5	5 days incl. weekend	Y	Y	1, 5-9
RF speed, if variable, else status	5	5 days incl. weekend	Y	Y	1, 5-9
Duct SP	5	5 days incl. weekend	Y	Y	1, 7, 9
Building SP differential	5	5 days incl. weekend	Y	Y	8
OSAT	5	5 days incl. weekend	Y	Y	All
OSA-WB or enthalpy, if enthalpy economizer	5	5 days incl. weekend	Y	Y	1, 3
Indoor dry-bulb ___ zones (expected to be most problematic)	5	5 days incl. weekend	Y	Y	All

Remarks:

CCV position (optional)
HCV position (optional)
SF cfm not required if not monitored
RF cfm not required if not monitored

- G. Acceptance Criteria (referenced by function or mode ID)
- 1-21. For the conditions, sequences and modes tested, the AHU, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
 2. AHU shall be able to maintain the SA temperature within 1.0F either side of the deadband of the current setpoint without excessive hunting.
 7. AHU and controls shall control the duct static pressure so that it does not drift more than an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.
- H. Sampling Strategy for Identical Units (xx% Sampling -- yy% Failure Rule is defined in Section 17100, Part 3.6)
1. All identical AHU's over 15 tons shall not have any sampling--test all units. However, 25% of the units may have monitoring be the verification method for modes listed with Monitoring or Both as testing methods, with no less than three units being fully tested per the above requirements.
 2. All identical AHU's equal to or less than 15 tons shall be tested as required above according to the 50% Sampling--20% Failure Rule. The other 50% shall be monitored for the modes listed above as needing monitoring.

END OF REQUIREMENTS FOR AHU TEST

4. **TERMINAL UNITS (TU)** (all types)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Terminal unit

PC-_____

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both ³	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, warmup, shutdown, unoccupied & manual modes and power failure and restoration. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with, including all damper, valve and fan functions.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Sensor activator calibration checks on: SAT, MAT, zone air temperature damper position and other random checks (EMS readout against visual or hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure setpoint, with an inclined manometer)	Manual	
3. Device and actuator calibration and stroke checks for heating coil valve and non-DDC dampers	Manual	
4. For the TU's tested, check the prefunctional checklist items.	Observation	
5. Verify control parameters and setpoints to be reasonable and appropriate by reviewing the full program of 5% of all the TU's with each other for consistency. Verify the max. and min. cfm setpoints of all tested TU's against the control drawing and TAB values. Verify other TU programming parameters such as K-factors, deadbands, setpoints, stroke times, etc.	Observation	
6. Verify no CCV flow when there is HCV flow	Either	
7. Verify no hunting or significant overshoot by damper or valves.	Either	
8. Verify by measurement, CCV & HCV positive shutoff (no leak-thru)	Manual	
9. Verification of minimum OSA control through varying VAV box positions, if applicable	Either	²
10. All alarms (fan status, low limits, high static, etc.)	Manual	
11. Verify that TU is maintaining space setpoint temperatures	Monitoring	Both Design
12. Verify airflows and pressures (this random test is part of the TAB test)	--	

¹Cooling season, Heating season or Both. "Design" means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

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

None

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Monitoring is required on 1/2 of the tested TU's. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each zone thermostat and space sensor and other critical areas, monitor:					
Space temperature	10	3 weekdays, summer design	Y	Y	11
Space temperature	10	3 weekdays, winter design	Y	Y	11
Space temperature	2	8 hours, occupied	Y	Y	7
Heating coil valve	2	8 hours, occupied	Y	Y	7
Damper position or cfm	2	8 hours, occupied	Y	Y	7

Remarks:

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

- 1-11. For the conditions, sequences and modes tested, the TU, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
10. Space temperature during occupied modes shall remain within 1°F of the ends of the deadband without excessive hunting of either the damper or coil valve.

H. Sampling Strategy for Identical Units (xx% Sampling -- yy% Failure Rule is defined in Section 17100, Part 3.6). Units of the same type and function, but different in size, are considered identical for sampling purposes.

1. Random sample according to the 10% Sampling -- 10% Failure Rule. This applies to the testing subsections. That is, if calibration is off on more than 10% of the tested TU's, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.

END OF REQUIREMENTS FOR TERMINAL UNIT TEST

5. PACKAGED DX AIR CONDITIONING OR HEAT PUMP UNITS

A. Parties Responsible to Execute Functional Test

- Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

- Unit (fans, coils, condenser, compressors, ducts, VFD)
- Heat recovery coil, humidifier or direct / indirect evaporative cooling sections

PC-_____

PC-_____

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both ³	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Mixed and supply air, and reset temp. control functions	Both	
3. Economizer functions	Both	Cooling
4. SF, RF and exhaust fan interlocks	Either	
5. Compressor unloading & condenser fan staging for head pressure control	Both	
6. Demand limiting control (if applicable)	Monitoring	Cooling
7. Duct static pressure (SP) control	Both	
8. Return or exhaust fan tracking and building SP	Monitoring	
9. VFD (or inlet vanes) operation on SF and RF: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, constancy of static pressure, verification of program settings, alarms, etc	Both	²
10. Damper interlocks and correct modulation in all modes, including fire and smoke dampers	Manual	
11. Temperature difference across heating and cooling coils, if spec'd	Manual	
12. Verification of minimum OSA quantity and control through varying VAV box positions	Either	²
13. Branch duct control damper control	Manual	
14. Night low and high limit, morning warmup cycle,	Either	
15. Heat recovery operation	Monitoring	
16. Verify TAB reported SF cfm with control system reading	Manual	²
17. All alarms (low limits, high static, freezestat, etc.)	Manual	
18. Unit heating and cooling capacity tests, optional	Manual	Design
19. Heating and cooling EER or COP efficiency tests, optional		Design
20. Change over function from heating to cooling and defrost (heatpumps)	Manual	

Function / Mode	Test Method Manual, Monitoring, Either or Both ³	Required Seasonal Test ¹
21. Sensor and actuator calibration checks on: duct static pressure sensor on units >10 tons, SAT, MAT, OSAT, economizer and RA dampers and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure setpoint, with an inclined manometer)	Manual	
22. Verify control strategies, schedules and setpoints to be reasonable and appropriate		

¹Cooling season, Heating season or Both. "Design" means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

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

- Reduced Testing for Smaller Units. For standard application AHU's less than 15 tons, the following modifications to the testing requirements apply: 1) either Manual or Monitoring will satisfy the verification requirement—where Both is listed, choose one. 2) Testing Modes 6, 8, 11, 13 and 16 is not required.

F. Required Monitoring

- All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each Unit being tested:					
RAT	5	5 days incl. weekend	Y	Y	1-3, 5, 19
SAT	5	5 days incl. weekend	Y	Y	1-3, 5
CC LAT	5	5 days incl. weekend	Y	Y	1-3, 5
HC LAT	5	5 days incl. weekend	Y	Y	1-3, 5
MAT	5	5 days incl. weekend	Y	Y	1, 3, 19
Indoor WB or enthalpy	5	5 days incl. weekend	Y	Y	1, 3
SF speed	5	5 days incl. weekend	Y	Y	1, 5-9
RF speed	5	5 days incl. weekend	Y	Y	1, 5-9
Duct SP	5	5 days incl. weekend	Y	Y	1, 7, 9
Building SP differential	5	5 days incl. weekend	Y	Y	8
OSAT	5	5 days incl. weekend	Y	Y	All
OSAT-WB or enthalpy	5	5 days incl. weekend	Y	Y	1, 3
Indoor dry-bulb zones	5	5 days incl. weekend	Y	Y	All
Compressor amps or stage	5	5 days incl. weekend	Y	Y	5
Condenser fan amps or stage	5	5 days incl. weekend	Y	Y	5

Remarks:

- G. Acceptance Criteria (referenced by function or mode ID)
- 1-22. For the conditions, sequences and modes tested, the system, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
 2. RTU shall be able to maintain the SA temperature within 1.0F either side of the deadband of the current setpoint without excessive hunting.
 7. RTU and controls shall control the duct static pressure so that it does not drift more than an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.
- H. Sampling Strategy for Identical Units (xx% Sampling -- yy% Failure Rule is defined in Section 17100, Part 3.6)
1. All identical AHU's over 30 tons shall not have any sampling--test all units. However, 25% of the units may have monitoring be the verification method for modes listed with Monitoring or Both as testing methods, with no less than three units being fully tested per the above requirements.
 2. All identical AHU's equal to or less than 30 tons shall be tested as required above according to the 50% Sampling--20% Failure Rule. The other 50% shall be monitored for the modes listed above as needing monitoring.

END OF REQUIREMENTS FOR PACKAGED UNIT TEST

6. BOILER SYSTEM (Heating Water)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls
2. HVAC mechanical contractor or vendor: assist in testing sequences

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Boiler	PC-_____
2. Primary HW supply pumps	PC-_____
3. Heating water piping system	PC-_____
4. Secondary HW supply pumps	PC-_____
5. VFD on secondary pumps	PC-_____

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

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u> ¹
11. Verify schedules and setpoints to be reasonable and appropriate		

¹Cooling season, Heating season or Both. "Design" means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

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

1. False load boiler, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each boiler and pump:					
Boiler current or status	5	5 days incl. weekend	Y	Y	1-3
HWST	5	5 days incl. weekend	Y	Y	1, 3
HWRT	5	5 days incl. weekend	Y	Y	1, 3
OSAT-DB	5	5 days incl. weekend	Y	Y	1-3
HWS primary pump current or status	5	5 days incl. weekend	Y	Y	1, 2
HWS secondary pump speed, if variable	5	5 days incl. weekend	Y	Y	1, 3
HWS secondary pump flow rate, if in EMS	5	5 days incl. weekend	Y	Y	1, 3
HWS secondary pump speed controlling parameter value	5	5 days incl. weekend	Y	Y	1, 3, 10

Remarks:

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

- 1-11. For the conditions, sequences and modes tested, the boilers, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. Boiler shall maintain the supply water setpoint to within +/- 1.0F of setpoint deadband without excessive hunting.
- 9.-10. Pumping system and controls shall maintain the current desired pressure setpoint to within an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.

H. Sampling Strategy for Identical Units (xx% Sampling – yy% Failure Rule is defined in Section 17100, Part 3.6)

1. No sampling, test all.

END OF REQUIREMENTS FOR BOILER SYSTEM TEST

7. EXHAUST FANS

The testing requirements apply to the following fans (check all that apply): central restroom, mechanical room, stairwell pressurization, elevator pressurization, kitchen hood, garage

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Exhaust fans

PC-

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both ¹	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Verify schedules and setpoints to be reasonable and appropriate		
3. Function at fire alarm (off, depressurization, etc.)	Manual	
4. Interlocks to building pressurization control	Manual	
5. Speed controls	Either	
6. Check TAB report record of sound power level tests and space pressures and compare to specifications	Review	
7. Sensor calibration checks on any controlling temperature or pressure sensor	Manual	

¹Refer to Special Procedures

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

None

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
For each fan:					
Do be determined					

Remarks:

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

- 1-6. For the conditions, sequences and modes tested, the fans, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

H. Sampling Strategy for Identical Units (xx% Sampling -- yy% Failure Rule is defined in Section 17100, Part 3.6)

1. All identical fans shall have the 20% Sampling -- 10% Failure Rule apply.

END OF REQUIREMENTS FOR EXHAUST FAN TEST

8. SERVICE HOT WATER SYSTEM

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Hot water heaters (heaters, mixing valves)
2. Recirculating pumps

PC- _____

PC- _____

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

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

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

<u>Function / Mode</u>	<u>Test Method</u> Manual, Monitoring, Either or Both	<u>Required</u> <u>Seasonal</u> <u>Test</u>
General		
1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with.	Manual	
In addition to, or as part of (1) above, the following modes or tests are required:		
2. Verify schedules and setpoints to be reasonable and appropriate		
3. Unoccupied pump operation	Either	
4. Mixing valve operation and temperature control	Either	
5. Sensor calibration checks on hot water temperature	Manual	

E. Special Procedures (other equipment to test with, etc.; reference to function ID) None

F. Required Monitoring None

G. Acceptance Criteria (referenced by function or mode ID) 1-6. For the conditions, sequences and modes tested, the fan's integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

H. Sampling Strategy for Identical Units (xx% Sampling -- yy% Failure Rule is defined in Section 17100, Part 3.6)

1. All identical fans shall have the 20% Sampling -- 10% Failure Rule apply.

END OF REQUIREMENTS FOR SERVICE HOT WATER SYSTEM TEST

9. BUILDING AUTOMATION SYSTEM (BAS)

Spec writer:

If all BAS controlled systems or equipment are not going to be functionally tested and trended, additional monitoring, trending and point-to-point checkout will be required above what is outlined below. In fact, the BAS cannot really be functionally tested without functionally testing all the equipment it controls.

- A. Parties Responsible to Execute Functional Test
 - 1. Controls contractor: operate the controls to activate the equipment.
- B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID
PC- _____
—

 - 1. Building Automation System
 - 2. All prefunctional checklists of controlled equipment
- D. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing.
- E. A significant part of the BAS functional testing requirements is the successful completion of the functional tests of equipment the BAS controls or interlocks with. Uncompleted equipment functional tests or outstanding deficiencies in those tests lend the required BAS functional testing incomplete.
- F. Integral or stand-alone controls are functionally tested with the equipment they are attached to, including any interlocks with other equipment or systems and thus are not covered under the BAS testing requirements, except for any integrated functions or interlocks listed below.
- G. In addition to the controlled equipment testing, the following tests are required for the BAS, where features have been specified. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in the specifications.

<u>Function / Mode</u>	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
MISC. FUNCTIONS	
1. All specified functions and features are set up, debugged and fully operable	Verbal discussion of features
2. Power failure and battery backup and power-up restart functions	Demonstration
3. Specified trending and graphing features demonstration	See equipment trends
4. Global commands features	Demonstration
5. Security and access codes	Demonstration
6. Occupant over-rides (manual, telephone, key, keypad, etc.)	Demonstration
7. O&M schedules and alarms	Demonstration
8. Scheduling features fully functional and setup, including holidays	Observation in terminal screens or printouts
9. Date and time setting in central computer and verify field panels read the same time	Demonstration

Function / Mode	Test Method Manual (demonstration), Monitoring, Either or Both
10. Included features not specified to be setup are installed (list)	Demonstration
11. Occupancy sensors and controls	Demonstration
12. Demonstrate functionality of field panels using local operator keypads and local ports (plug-ins) using portable computer/keypad	Demonstration of 100% of panels and 10% of ports
13. All graphic screens and value readouts completed	Demonstration
14. Setpoint changing features and functions	Done during equipment testing
15. Communications to remote sites	Demonstration
16. Sensor calibrations	Sampled during equipment tests
17. "After hours" use tracking and billing	
18. Final as-builts or redlines (per spec) control drawings, final points list, program code, setpoints, schedules, warranties, etc. per specs, submitted for O&Ms.	Observation
19. Verify that points that are monitored only, having no control function, are checked for proper reporting to BAS.	Observation
INTEGRATED TESTS	
20. Fire alarm interlocks and response	Demonstration
21. Duty cycling (if specified)	Monitoring
22. Demand limiting (including over-ride of limiting)	Monitoring
23. Sequential staging ON of equipment	Either
24. Optimum start-stop functions	Monitoring
25. All control strategies and sequences not tested during controlled equipment testing	Either
26. Other integrated tests specified in the contract documents	
27. Security system interlocks	Demonstration
28. Fire protection and suppression systems	Demonstration

H. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

I. Additional Required Monitoring

- Besides the trending and monitoring required with the functional testing of equipment, all points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

Point	Time Step (min.)	Minimum Time Period of Trend	Hard Copy? (Y/N)	ASCII File? (Y/N)	Function Being Tested
Misc. equipment current or status for duty cycling and demand limiting	5	5 days incl. weekend	Y	Y	21-22
Equipment or building kW or current for demand limiting	5	5 days incl. weekend	Y	Y	21-22
Optimum start/stop equip.	5	5 days incl. weekend	Y	Y	24

Remarks:

- I. Acceptance Criteria (referenced by function or mode ID)
All For the conditions, sequences and modes tested, the BAS, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
- J. Sampling Strategy for Identical Units (xx% Sampling – yy% Failure Rule is defined in Section 17100, Part 3.6)
 - 1. Sampling of field panels and local ports for procedures 9 and 12 above, with a 10% Failure Rule.

END OF REQUIREMENTS FOR BAS TEST

10. TEST AND BALANCE WORK (TAB)

- A. Parties Responsible to Execute Functional Test
1. TAB contractor: perform checks using test instruments.
 2. Controls contractor: operate the controls to activate the equipment.
- B. Integral Components or Related Equipment Being Tested Prefunctional Checklist ID
1. TAB water-side PC-_____
 2. TAB air-side PC-_____
- C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing.
- D. Purpose. The purpose of this test is to spot check the TAB work to verify that it was done in accordance with the contract documents and acceptable practice and that the TAB report is accurate.
- E. The following tests and checks will be conducted. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

<u>Test or Check</u>	<u>Test Method</u>	<u>Required Seasonal Test³</u>
<p>1. A random sample of up to _____ % the TAB report data shall be selected for verification (air velocity, air or water flow rate, pressure differential, electrical or sound measurement, etc.). The original TAB contractor will execute the checks, witnessed by the commissioning authority. The TAB contractor will use the same test instruments as used in the original TAB work.</p> <p>A failure¹ of more than 10% of the selected items of a given system² shall result in the failure of acceptance of the final TAB report and the TAB contractor shall be responsible to rebalance the system, provide a new total system TAB reports and repeat random verifications of the new TAB report.</p> <p>The random testing will include the verification of minimum outdoor air intake flows at minimum, maximum and intermediate total airflow rates for _____% of the air handlers. Other selected data to be verified will be made known upon day of testing.</p>	Demonstration	Cooling Design
2. Verify that settings of all valves, splitters, dampers and other adjustment devices have been permanently marked by the Contractor, after completion and acceptance of functional testing.	Demonstration	
3. Verification that the air system is being controlled to the lowest possible static pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from fan to diffuser having all balancing dampers wide open.	Demonstration	
4. Verification that the water system is being controlled to the lowest possible pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from the pump to the coil having all balancing valves wide open.	Demonstration	

¹Failure of an item is defined as follows:

For air flow: a deviation of more than 10% of instrument reading

For temperatures: a deviation of more than 1°F

For air and water pressures: a deviation of more than 10% of full scale of test instrument reading

For sound pressures: a deviation of more than 3 decibels. (Variations in background noise must be considered)

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

³Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

F. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

G. Required Monitoring
None

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

J. Sampling Strategy for Identical Units
Described in test table above.

END OF REQUIREMENTS FOR TAB TEST

11. INDOOR AIR QUALITY CHECK (IAQ)

IAQ checking activities are not technically “functional testing.” However, they are included here for consistency. Indoor air quality (IAQ) commissioning does not ensure that indoor air quality will be adequate or without deficiency at building turnover or during occupancy, unless the owner has specifically specified that actual air quality testing be performed. Commissioning for indoor air quality entails performing tasks that minimize the potential for IAQ problems, but it does not eliminate their possibility. The primary source for this checklist was Annex C in *ASHRAE Guideline 1-1989R The HVAC Commissioning Process*, Public Review Draft, 1996.

Spec Writer:

The IAQ checks here should be carefully reviewed for completeness and applicability to the current project and the Owner's documented program regarding IAQ. In particular, specifying any actual “testing” can have significant cost and liability ramifications.

- A. Parties Responsible to Perform IAQ Checks
 - 1. Commissioning agent: performs and oversees checks, inspections and reviews.
 - 2. TAB contractor: performs checks using test instruments for tasks under Part C
- C. Prerequisites CA will perform each check and review as soon as the materials or work is such that IAQ related determinations can be made.
- D. Purpose. The purpose of the IAQ check is to minimize the potential for IAQ problems in the facility during occupancy. The CA is not responsible for any IAQ issues during construction, nor for IAQ issues in the occupied part of the facility, if construction is being performed in other parts of the facility.
- E. The following tasks will be conducted and documented:

Spec Writer: Edit and enhance this list as appropriate. Performing all tasks on this list is currently rarely done by commissioning agents.

More specificity will also be needed on many of the tasks before the TAB and CA can bid this work.

1. Submittal Reviews

Compare specified data with submitted data sheets for the following:

- a. Filtration and filter type.
- b. Materials that had specifications for emissions rates as part of the contract documents.
- c. HVAC materials that have a potential for airflow erosion, corrosion and microbial contamination (HVAC insulation materials, etc.).
- d. Manufacturer's safety data sheets (MSDS) for products specified in the contract documents that may be suspected contributors to indoor pollutants (carpets, flooring, fabrics, adhesives, wall coverings, partitions, and ceilings; insulating and fire-proofing materials; sealants on walls and floors; use of preservatives, paints, varnishes, and other finish materials).

2. Static Inspections and Checks

- a. Review the code compliance calculations for accuracy.
- b. Verify that the outdoor air intakes are sized and located according the plans and specifications.
- c. Verify that no outside conditions exist that could compromise the quality of the air entering the outdoor intakes.
- d. Inspect air intakes and exhausts for short-circuiting.
- e. Document any required ductwork cleaning.
- f. Prior to building turnover, verify that final filters are installed and coils, inside of units and ductwork is clean.
- g. Inspect air supply system components to ensure control and minimization of the presence of free and standing water and to minimize microbial contamination (condensate trays, traps, humidifiers, water baffles, mist eliminators and cooling towers).
- h. Verify proper access for cleaning of both sides of coils, condensate pans and/or humidifier reservoirs in all HVAC equipment.
- i. Meet with contractors and review any specified manufacturer's recommended curing, drying and airing procedures (for minimizing emission rates). Document the compliance of the contractors.
- j. When the building is partially occupied during construction, meet with the Contractor and issue a plan in writing for operation of the HVAC system. The plan will describe how the system can be operated at as close to normal operating conditions as possible, to minimize dust and dirt from contaminating the ductwork and coils and polluting the occupied areas, and to prevent damaging moisture migration.
- k. Review TAB reports for consistency with the specifications.
- l. After completion of TAB, review with the TAB contractor, any areas they may consider as being potentially problematic regarding maintaining adequate minimum outdoor air, proper exhaust or room pressure differential.

3. Air Flow and Pressurization Checks

- a. Verify that the specified minimum ventilation rates are maintained during all occupied modes of operation, particularly during VAV terminal box turn-down.
- b. Spot-check TAB supply air flow readings in critical areas.
- c. Spot-check the TAB measurements and setup of the exhaust systems for each area. When purging is specified in the contract documents, develop a plan for, and see that the Contractor purges the building prior to occupancy.
- d. Verify that the total building pressurization criteria is met through varying HVAC loads and economizing conditions.
- e. Verify that room pressure differentials are as specified between critical areas (clean rooms, bio-hazards, film developing rooms, chemical storage areas, etc.).
- f. Verify that the design engineer's specification for interstitial and area pressurization differentials has been met.

Spec Writer: The following procedures require considerably more detail than is given here to specify a requirement. The verification concepts are mentioned for reference only.

4. Verification

- a. Verify that the specified ventilation effectiveness throughout the various areas of the building is being met by: ___ smoke tube testing for airflow patterns, ___ flow hood readings, ___ air contaminant monitoring, ___ other _____.
- b. Perform IAQ testing using the following methods (surface cultures for microbial contamination, airborne culture testing, CO₂ monitoring, VOC monitoring, CO monitoring, etc.).

I. Acceptance Criteria

Unless noted in the requirements, the commissioning agent in concert with the CM will make determinations and interpretations for when IAQ issues are considered to be in compliance with the contract documents.

END OF IAQ REQUIREMENTS

END OF THIS GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15998 PREFUNCTIONAL CHECKLISTS

MECHANICAL and ELECTRICAL

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

SECTION 15998

PREFUNCTIONAL CHECKLISTS

MECHANICAL and ELECTRICAL

A. GENERAL

This section contains representative Prefunctional Checklists in a form format (PC).

The PC procedures displayed in a form format here are intended to provide the CA with an example of a format and an indication of the rigor of the required prefunctional checklists and documentation for various equipment types. Though they were not developed specifically for this project, they are generally applicable.

The checklists contain items for both Division 15 and 16 contractors to perform. On each checklist, a column is provided that should be filled out by the Contractor assigning responsibility for that line item to a trade. Those executing the checklists are only responsible to perform items that apply to the specific application at hand. These checklists do not take the place of the manufacturer's recommended checkout and start-up procedures or report. Some checklist procedures may be redundant of some checkout procedures that will be documented on typical factory field checkout sheets. Double documenting is required in those cases.

Refer to Section 17100 for additional requirements regarding prefunctional checklists, startup and initial checkout. Items that do not apply should be noted along with the reasons on the form. If this form is not used for documenting, one of similar rigor and clarity shall be used. Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off. "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor.

B. PREFUNCTIONAL CHECKLISTS

This guide specification section continues with prefunctional checklists for the following equipment. The checklists are provided in electronic file format (Word 6.0 for Windows 3.1). The file name is at the bottom of each page. The file name extension “pc_” stands for Prefunctional Checklist and the last digit is the version number. Any MS Excel spreadsheet files are noted with their usual .xls extension.

COMPONENT

ELECTRONIC FILE NAME

Mechanical Equipment (checklists have both mechanical and electrical parts)

Air handler unit	ahu.pc_
Air cooled condenser and compressor	aircndsr.pc_
Boiler	boiler.pc_
Condenser water piping	cdwpipe.pc_
Chiller	chiller.pc_
Chiller system sample startup documentation plan	chilrdoc.pc_
Chilled water piping	chwpipe.pc_
Computer room AC unit	computac.pc_
Controls system (BAS)	controls.pc_
Cooling tower	cooltwr.pc_
Exhaust fan	exh_fan.pc_
Fan coil unit	fancoilu.pc_
Heating water piping	hwpipe.pc_
Packaged roof top unit	pkgunit.pc_
Pump (water)	pump.pc_
Startup documentation plan template	startpln.c08
TAB	tabplan.pc_
Terminal unit	tu_pc05.xls
Variable frequency drive	vfd.pc_

C. SUGGESTED NUMBERING KEY FOR COMMISSIONING PROCEDURES

The checklists, functional tests, documentation and training use the following identification numbering:

At the beginning of the identification number is a text abbreviation for the following:

Document or Event Abbreviations

DOC	= Documentation
PC	= Prefunctional Checklist
SP	= Startup Plan
SR	= Startup Report
FT	= Functional Test
R	= Review
TR	= Training Record

Prefunctional Checklist Numbering Key

FT-0102.3: The first four digits uniquely identify the piece of equipment to the component level. The first 2 digits are the System Type, the second 2 digits are an arbitrary component number (not necessarily the same as the specified ID number). The number after the decimal is the test number. For example, FT-0102.3 = Functional Test 3 of system Type 1, component number 2 (e.g., 0102.3 = Chiller #2, FT #3, because chillers are system Type 1). Other components under chillers are: additional chillers, pumps, valves, piping; VFDs. The component number of 00 means “general” or “all” components, as with the entire system. All tests, procedures, trainings and records should have the same first 4 digits for any given equipment component.

Another example is TUs. If there were only 1 TU type, then tests would be numbered FT-0500.1, 0500.2, etc. If there were 2 types of TUs: FT-0501.1, 0501.2, etc and 0502.1, 0502.2, etc.

An *example* of the number system follows:

0100	Chilled Water System	0200	Boiler System
0101	Chiller 1	0201	Boiler 1
0102	Chiller 2	0202	Boiler 2
0103	Cooling tower 1	0203	Pump HWP-1
0104	Cooling tower 2	0204	Pump HWP-2
0105	Pump CHWP-1	0205	HW piping
0106	Pump CHWP-2	0206	Sensor calibration
0107	CHW piping		
0108	CDW piping		
0109	Sensor calibration		
		etc.	

Numbers for Primary System Types and Components

Components are in parentheses.

- 01 Chilled water system (chillers, cooling towers, pumps, condensers, piping, valves)
- 02 Hot water system (boilers, hot water pumps, valves, piping)
- 03 Air handler units (SF, RF, coils, valves, VFD, ducts, dampers)
- 04 Packaged, AC or HP units (SF, RF, coils, valves, VFD, ducts, dampers, compressors, condensers)
- 05 Terminal units
- 06 Computer room AC units
- 07 Unit heaters or AC spot coolers
- 08 Heat exchangers
- 09 Service water system
- 10 Test and balance (TAB)
- 11 Building automation system (controls)
- 12 Lighting controls
- 13 Specialty fans
- 14 Fume hoods

END OF SECTION

Prefunctional Checklist

Project _____

PC-03 AIR HANDLER UNIT, AHU #'s _____

Components included: _____ supply fans, _____ return and exhaust fans, _____ coils,
_____ valves, _____ VFD, _____ dampers

Associated Checklists: CHW, HW Piping, _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents for given trade.....** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag--->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Volts/phase 2						
3						

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Cabinet and General Installation							
Permanent labels affixed, including for fans							
Casing condition good: no dents, leaks, door gaskets installed							
Access doors close tightly - no leaks							
Boot between duct and unit tight and in good condition							
Vibration isolation equipment installed & released from shipping locks							
Maintenance access acceptable for unit and components							
Sound attenuation installed							
Thermal insulation properly installed and according to specification							
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Clean up of equipment completed per contract documents							
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed							
Valves, Piping and Coils (see full piping checklists)							
Pipe fittings complete and pipes properly supported							
Pipes properly labeled							
Pipes properly insulated							
Strainers in place and clean							
Piping system properly flushed							
No leaking apparent around fittings							
All coils are clean and fins are in good condition							
All condensate drain pans clean and slope to drain, per spec							
Valves properly labeled							
Valves installed in proper direction							
OSAT, MAT, SAT, RAT, chilled water supply sensors properly located and secure (related OSAT sensor shielded)							
Sensors calibrated (See calibration section below)							
Motors: Premium efficiency verified, if spec'd?							
P/T plugs and isolation valves installed per drawings							
Fans and Dampers							
Supply fan and motor alignment correct							
Supply fan belt tension & condition good							
Supply fan protective shrouds for belts in place and secure							
Supply fan area clean							
Supply fan and motor properly lubricated							
Return/exhaust fan and motor aligned							
Return/exhaust fan belt tension & condition good							
Return/exhaust fan protective shrouds for belts in place and secure							
Return/exhaust fan area clean							
Return/exhaust fan and motor lube lines installed and lubed							
Filters clean and tight fitting							
Filter pressure differential measuring device installed and functional (magnahelic, inclined manometer, etc.)							
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)							
All dampers close tightly							
All damper linkages have minimum play							
Low limit freeze stat sensor located to deal with stratification & bypass							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Ducts (preliminary check)							
Sound attenuators installed							
Duct joint sealant properly installed							
No apparent severe duct restrictions							
Turning vanes in square elbows as per drawings							
OSA intakes located away from pollutant sources & exhaust outlets							
Pressure leakage tests completed							
Branch duct control dampers operable							
Ducts cleaned as per specifications							
Balancing dampers installed as per drawings and TAB's site visit							
Electrical and Controls							
Pilot lights are functioning							
Power disconnects in place and labeled							
All electric connections tight							
Proper grounding installed for components and unit							
Safeties in place and operable							
Starter overload breakers installed and correct size							
Sensors calibrated (see below)							
Control system interlocks hooked up and functional							
Smoke detectors in place							
All control devices, pneumatic tubing and wiring complete							
VFD							
VFD powered (wired to controlled equipment)							
VFD interlocked to control system							
Static pressure or other controlling sensor properly located and per drawings and calibrated							
Static pressure or other controlling sensor calibrated							
Drive location not subject to excessive temperatures							
Drive location not subject to excessive moisture or dirt							
Drive size matches motor size							
Internal setting designating the model is correct							
Input of motor FLA represents 100% to 105% of motor FLA rating							
Appropriate Volts vs Hz curve is being used							
Accel and decel times are around 10-50 seconds, except for special applications. Actual decel = _____ Actual accel = _____							
Lower frequency limit at 0 for VAV fans and around 10-30% for chilled water pumps. Actual = _____							
Upper frequency limit set at 100%, unless explained otherwise							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Unit is programmed with full written programming record on site							
TAB							
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents							
Final							
Smoke and fire dampers and unpowered TU's are open							
Startup report completed with this checklist attached							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
If unit is started and will be running during construction: have quality filters on RA grills, etc. to minimize dirt in the ductwork and coils and in any finished areas. Verify moisture migration is not a problem, due to improper pressures between spaces.							

- **The checklist items of Part 4 are all successfully completed for given trade.**____ **YES** ____ **NO**

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Supply fan rotation correct							
Return/exhaust fan rotation correct							
Fans > 5 Hp Phase Checks: (%Imbalance = 100 x (avg. - lowest) / avg.) Record all 3 voltages in cell. Imbalance less than 2%?							
Record full load running amps for each fan. _____rated FL amps x _____srvc factor = _____ (Max amps). Running less than max?							
Return /exhaust fan acceptable noise & vibration							
Supply fan has no unusual noise or vibration							
Inlet vanes aligned in housing, actuator spanned, modulate smoothly and proportional to input signal and EMS readout							
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated (follow procedure similar to valves Section 7 below). List each actuated damper here when spanned:							
Valves stroke fully and easily and spanning is calibrated (see Section 7 below). List each actuated valve here when spanned:							
Valves verified to not be leaking through coils when closed at normal operating pressure (see Section 7 below)							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
The HOA switch properly activates and deactivates the unit							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

- **The checklist items of Part 5 are all successfully completed for given trade.** ☐ YES ☐ NO

6. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors are calibrated within required tolerances**..... ☐ YES ☐ NO

7. Misc. Procedures (Referenced above)

7.1. Sensor Calibration Methods

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or

Notes:

building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

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

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. **Method 1--Water Temperature With 2-Way Valve.** Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. **Method 2--Air Temperature With 2 or 3-Way Valve.** Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- C. **Method 3 Coil Drain Down (not for 3-way valves).** Put systems in normal mode. If cooling coil valve, remove all call for cooling or if heating coil valve put system in full cooling. Close isolation valve on supply side of coil, open air bleed cap, open drain-down cock and drain water from coil. Water should stop draining, else there may be a leak through the control valve. Return all to normal when done.

7.3 Valve Stroke Setup and Check

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

Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). **For heating coil valves (NO):** Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

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

— END OF CHECKLIST—

Notes:

Prefunctional Checklist

Project _____

PC-04_____ AIR COOLED CONDENSER and COMPRESSOR
(For AC or Split Heat Pump) ID#'s _____

Components included: FCU-_____, _____,

Associated Checklists: _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- Documentation complete as per contract documents for given trade **YES** **NO**

3. Model verification

[Contr =]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Volts/Ph/A 2						
3						
1						
Min. OSAT 2						
3						

- The equipment installed matches the specifications for given trade..... **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
GENERAL INSTALLATION							
Permanent labels affixed, including for fans							
Casing condition good: no dents, leaks, door gaskets installed							
All coils are clean and fins are in good condition							
Vibration isolation bolts loosened							
Maintenance access acceptable for unit and components							
Clean up of equipment completed per contract documents							

Notes:

AIR-COOLED CONDENSER & COMPRESSOR CHECKLIST

PC-04

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
PRE-START REQUIREMENTS							
Piping and Coils							
Refrigerant piping sized according to mf'r's literature							
Refrigerant piping in good condition and suction insulated							
Liquid line solenoid valve located at evaporator coil, as required							
Compressor, liquid and suction line service valves open							
Site Charging							
Refrigerant lines evacuated and dehydrated per mf'r recommendations							
Refrigerant charged by strictly using mf'r recommended procedures and accurate instruments.							
Charging method used: Outside air temperature during charging: _____							
Final charging points are within 2°F liquid line or within 10psig head pressure (depending on method used) of optimal. Attach charging chart with final points marked with this report, including all calculations to determine optimal subcooling point.							
Leak checks made with leak detector around compressor, condenser, evaporator, TXVs, solenoid valves, filter driers and fusible plugs and other piping fittings. All leaks repaired.							
Refrigerant sight glass clear of bubbles (if OSAT>70F)							
Moisture indicator shows no moisture							
Compressor and Condenser							
Correct oil level (check site glass during operation, if available)							
Adequate clearance for airflow around condenser							
Crankcase heater (if applicable) energized long enough for startup							
Electrical and Controls							
Proper power supply for unit							
Power disconnects in place and labeled							
All electric connections tight							
Proper grounding installed for components and unit							
Indoor unit operable and providing design air flow							
Circuit protection sized and installed properly							
Control system interlocks hooked up and functional							

- The checklist items of Part 4 are all successfully completed for given trade. YES NO

Notes:

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Condenser fan rotation correct							
Measure line to line voltage phase imbalance for 1/3 of the compressors: Compressor 1 Phase: (%Imbalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) Record in cell, all three phase voltages. Imbalance less than 2%?							
Compressor 2 Phase: (%Imbalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) Record in cell, all three phase voltages. Imbalance less than 2%?							
Record full load running amps for each compressor. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?							
Fans > 5 Hp Phase Checks: (%Imbalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) Record all 3 voltages in cell. Imbalance less than 2%?							
Record full load running amps for each fan. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?							
No unusual noise or vibration during operation (condenser fan & compressor)							
Adjust the space temperature controls to cause a call for cooling. Verify that compressor starts and that supply air is cooled as expected.							
After 15 minutes of operation, record the readings in the following table.							
Remove the call for cooling. Observe that compressor cycles off.							
Crankcase heater remains on when unit cycles off (if required)							
Startup report completed with this checklist attached							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
Functional test procedures for this equipment reviewed and approved by installing contractor							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

- The checklist items of Part 5 are all successfully completed for given trade. YES NO

Notes:

Operational Record

Indoor fan speed _____	Discharge pressure _____	Evap entering air WB _____
Condenser fan speed _____	Discharge line temp _____	Evap leaving air DB _____
Oil pressure (optional) _____	Entering cond. air temp. _____	Evap leaving air WB _____
Suction pressure _____	Leaving cond. air temp. _____	Compressor amps _____
Suction line temp. _____	Evap. entering air DB _____	(L1 / L2 / L3)

6. Sensor Calibration

[_____]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N _____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors and actuators are calibrated within required tolerances.....** ☐ YES ☐ NO

7. Misc. Procedures (as referenced above)**7.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test

Notes:

instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

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

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. **Method 1--Water Temperature With 2-Way Valve.** Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. **Method 2--Air Temperature With 2 or 3-Way Valve.** Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

-- END OF CHECKLIST--

Notes:

Prefunctional Checklist

Project _____

PC-02_____ BOILER #'s _____

Associated checklists: Boiler, Heating Water Piping, HW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative Date

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents.....** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Volts/Ph/A 2						
3						
1						
2						
3						

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Physical Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
General appearance good, no apparent damage							
Site sufficiently clean for testing							
Equipment labels affixed							
Tube pulling, and access door space adequate							
Required seismic restraints in place							
Flue completely installed and sloped properly							
Combustion air supply complete							
System filled							

Notes:

BOILER PREFUNCTIONAL CHECKLIST

PC-02_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Pressure gages installed							
Thermometers installed							
Pressure gages installed							
P/T plugs installed as per drawings							
Multiple boiler interlocks completed							
Piping (Immediately around unit. Full piping in HW Piping Checklist.)							
Gas piping installed and tested (supply is at proper pressure)							
Hydronic piping complete, including blowdown system, makeup water piping and safety reliefs							
Hydronic system flushing complete and strainers cleaned							
Isolation valves and balancing valves installed							
Pipe fittings and accessories complete							
Test ports installed near all control sensors and per spec							
Flow switch installed as required							
Flow meters installed as required							
Piping type and flow direction labeled on piping							
Chemical treatment system or plan installed							
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank							
Expansion tanks verified to not be air bound and system completely full of water							
Air vents and bleeds at high points of systems functional							
Electrical and Controls							
Power to unit and disconnect installed							
All electrical components grounded							
Sensors calibrated (see below)							
Control system interlocks hooked up and functional							
All control devices, pneumatic tubing and wiring complete							
Motorized valves, dampers and float switches functional							
Fire and smoke sensing components functional							
Final							
Startup report completed with this checklist attached							
Startup report includes written certification from boiler manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
Heating water piping and pumps prefunctional checklists completed							

- The checklist items of Part 4 are all successfully completed for given trade. YES NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Boiler safeties energized and tested							
Startup report includes optimal and actual percent CO ₂ , CO, O ₂ , stack temperature; combustion efficiency							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

- The checklist items of Part 5 are all successfully completed for given trade. YES NO

6. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- All sensors are calibrated within required tolerances..... YES NO

Notes:

7. Misc. Procedures (Referenced above)

7.1. Sensor Calibration Methods

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

- A. **Sensors Without Transmitters--Standard Application.** Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. **Sensors With Transmitters--Standard Application.** Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. **Critical Applications.** For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watthour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. **Method 1--Water Temperature With 2-Way Valve.** Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. **Method 2--Air Temperature With 2 or 3-Way Valve.** Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override valves or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

7.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST –

Notes:

Prefunctional Checklist

Project _____

PC-01_____ CONDENSER WATER PIPING_____

Components Included: All valves, except coil valves

Associated checklists: Chiller, Cooling Tower, CHW Piping, CHW & CDW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor Date

Controls Contractor Date

Electrical Contractor Date

Sheet Metal Contractor Date

TAB Contractor Date

General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date

Owner's Representative Date

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data							
Flushing and cleaning plan							
O&M manuals							

- **Documentation complete as per contract documents for given trade** **YES** **NO**

3. Physical Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Y / N	Contr.
Piping		
Pipe fittings complete and pipes properly supported		
Required seismic anchoring installed		
Pipes properly labeled		
Pipes properly insulated		
Strainers in place and clean		
Isolation valves and balancing valves installed		
Test ports (P/T) installed near all control sensors and as per spec		
Flushing and cleaning plan submitted and approved		
Piping system properly flushed and cleaned and temporary piping removed (report attached)		
Piping pressure tested according to contract documents (report attached)		
Chemical treatment system or plan installed		
Water treatment report submitted according to contract documents		
No leaking apparent around fittings		
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank		
Expansion tanks verified to not be air bound and system completely full of water		
Air vents and bleeds at high points of systems functional		
Valves (except coil valve checklists are with the unit checklist)		
Valve labels permanently affixed		
Valves installed in proper direction		

Notes:

Check	Y / N	Contr.
No leaks		
Valves stroke fully and easily and spanning is calibrated (see Section 5.2 below)		
Valves that require a positive shut-off are verified to not be leaking when closed at normal operating pressure		
Sensors and Gages		
Temperature, pressure and flow gages and sensors installed		
Sensors calibrated (See calibration section below)		
TAB		
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents		

● **The checklist items of Part 3 are all successfully completed for given trade.**____ **YES** ____ **NO**

4. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

● **All sensors are calibrated within required tolerances**.....____ **YES** ____ **NO**

Notes:

5. Misc. Procedures (As referenced above)**5.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watthour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

5.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

5.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST –

Notes:

Prefunctional Checklist

Project _____

PC-01_____ CHILLER #'s _____

Associated checklists: Cooling Tower, Chilled & Condenser Water Piping, CHW and CDW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor_____
Date_____
Controls Contractor_____
Date_____
Electrical Contractor_____
Date_____
Sheet Metal Contractor_____
Date_____
TAB Contractor_____
Date_____
General Contractor_____
Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent_____
Date_____
Owner's Representative_____
DateNotes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents.....** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Volts/Ph/A 2						
3						
1						
Refrigerant 2						
3						
1						
Starter Model 2						
3						
1						
2						
3						

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
General appearance good, no apparent damage							
Proper vibration isolaters installed and adjusted							
Seismic restraints in place							
Isolation valves and balancing valves installed							

Notes:

CHILLER PREFUNCTIONAL CHECKLIST

PC-01_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Pipe fittings and accessories complete							
Pipes not supported on chiller							
Hydronic system flushing complete and strainers cleaned							
Cooling tower or condenser system checked out							
Evaporator air vent provided							
Water cooled condenser air vent provided							
Refrigerant relief pipe extended to outside							
Thermometers installed							
Pressure gages installed							
Test plugs installed near all control sensors and as per spec							
Flow switch installed as required							
Flow meters installed							
Proper refrigerant level							
No refrigerant leakage							
Proper oil types							
Proper oil level							
Purge unit installed, if specified							
Piping type and flow direction labeled on piping							
Equipment labels affixed							
Oil heater installed properly							
Size of overcurrent heater in motor starter correct							
Oil filter clean							
Electrical and Controls							
Power wiring installed properly							
All electrical components grounded properly							
Control wiring and control system hooked up							
Sensors calibrated (see calibration section below)							
Control system interlocks hooked up and functional							
Smoke detectors in place							
All control devices, pneumatic tubing and wiring complete							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
Chilled water piping and pumps prefunctional checklists completed							

• **The checklist items of Part 4 are all successfully completed for given trade.** ___ YES ___ NO

•

Notes:

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Measure line to line voltage phase imbalance for compressor: (%Imbalance = 100 x (avg. - lowest) / avg.) Record imbalance of compressor. Imbalance less than 2%?							
Record full load running amps for compressor. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?							
No unusual noise and vibration when running							
Compressor interlocking with oil pressure							
Adequate oil pressure when compressor shaft is turning							
Prerotation vane closed before compressor reaches full speed							
Prerotation vane steady when load changes							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							
Startup report completed with this checklist attached. (Includes full listing of all internal settings with notes as to which settings are BAS controlled or monitored and which are integral.							
Startup report includes written certification from chiller manufacturer that all specified features, controls and safeties have been installed and are functioning properly and that the installation and application comply with the manufacturer's recommendations.							

6. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Notes:

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors are calibrated within required tolerances.....** ☐ **YES** ☐ **NO**

Notes:

7. Misc. Procedures (as referenced above)**7.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override valves or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

7.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST –

Notes:

EXAMPLE

~~EXAMPLE~~

Documenting Requirements for Chiller System Startup and Initial Checkout

Project _____

Date _____

The purpose of documenting the startup and checkout process is to ensure to the Owner that all recommended startup and initial checkout procedures are completed and that a written record of the work is generated.

PLAN and PROCEDURES:

1. The prefunctional checklists provided by _____, should be filled out and signed (pumps, piping, chillers, cooling towers, water treatment).
2. The following pages shall be copied from the submitted manuals. Each paragraph, installation task or feature on each page listed shall be checked and dated when completed, or written notes shall be provided for why this item was not done or does not apply. A signature and date of the technician shall be provided at the bottom of each page. Settings established or readings made for any of the tasks shall be clearly recorded.
3. This list of references does not constitute a recommendation of the full installation and startup procedures or release the installer from following all factory recommendations, the specifications, applicable codes and good practice. Other pages applicable to this piece of equipment or other procedures completed should be added.
4. Other startup record forms normally used should also be filled out and submitted.
5. All documentation will be submitted to _____ upon completion and is required prior to TAB or functional testing execution.

Chiller-1 and 2 (each chiller has own pages)

1. McQuay IM 306, p. 4-5, Location and Mounting and Oil Cooler Piping and Vent Piping.
2. McQuay IM 306, p. 5-7, Electrical
3. McQuay IM 306, p. 8, Electrical Testing Control Circuit and Surge Capacitors.
4. McQuay IM 306, p. 10, Factory startup form and warranty registration form (also sent to manufacturer).
5. McQuay IM 306, p. 11 Prestart Checklist.
6. McQuay IM 616, p. 30-31, Pre-Start Checkout.
7. McQuay IM 616, p. 33 Startup.
8. McQuay IM 561, p.7, Installation and Pre-start Checks.
9. McQuay All changes to any Control Menu default values will be listed adjacent to the default values. Significant departures from the defaults will be explained in writing.

Chiller-3

1. McQuay IM 224 p. 4, Location.
2. McQuay IM 224 p. 5, Vibration Isolators.
3. McQuay IM 224 p. 8 and 9, Water Piping.
4. McQuay IM 224 p. 10, Flow Switch.
5. McQuay IM 224 p.13, Water Pressure Drop.
6. McQuay IM 224 p. 20, Relief Valve Piping.
7. McQuay IM 224 p. 40, Wiring.

EXAMPLE

8. McQuay IM 224 p.56, Pre-Start-up and Start-up.
9. McQuay IM 224, p. 71, Factory startup form and warranty registration form (also sent to manufacturer).
10. McQuay IM 493 p. 25-31, all changes to any Control Menu default values will be listed adjacent to the default values. Significant departures from the defaults will be explained in writing.

Cooling Tower

1. Baltimore Aircoil M244/1-0AA, p. 4, including "After 24 Hours" requirements.
2. According to M244, p. 4, provide documentation of motor amperage and voltage readings for each phase and compare to nameplate.

Name plate = 480 V, 9.1/30.0 FLA.

	Pony-1	Main-1	Pony-2	Main-2	Pony-3	Main-3
Ph-1 V						
Ph-2 V						
Ph-3 V						
% Imbalance*						
Ph-1 A						
Ph-2 A						
Ph-3 A						
% Imbalance*						

* % Imbalance = 100 x (avg. Volts or amps - lowest phase volts or amps) / avg. volts or amps

$$\text{Avg.} = (\text{Phase A} + \text{B} + \text{C}) / 3$$

The phase imbalance should be less than 2%.

3. If using a continuous bleed rate, provide calculation and final rate.
4. Provide the following documentation on the sump heaters and vibration alarm checkout, per specification 15710, 3.2.B.

<p><u>CT Sump Heaters.</u></p> <p>Schedule: (setpoint = 45F)</p> <table border="0"> <thead> <tr> <th></th> <th><u>ON (F)</u></th> <th><u>OFF (F)</u></th> </tr> </thead> <tbody> <tr> <td>Stage 1</td> <td>45</td> <td>43</td> </tr> <tr> <td>Stage 2</td> <td>47</td> <td>45</td> </tr> </tbody> </table> <p>Starting with sump heaters not running, overwrite sump temperature to be equal to stage 1 SPt. Then, lower to stage 2 SPt. Then raise to 1 F above 2nd stage OFF SPt. Then lower to 1st stage OFF SPt. Repeat for each CT.</p>		<u>ON (F)</u>	<u>OFF (F)</u>	Stage 1	45	43	Stage 2	47	45	<p><u>Actual:</u></p> <table border="0"> <thead> <tr> <th></th> <th><u>ON (F)</u></th> <th><u>OFF (F)</u></th> </tr> </thead> <tbody> <tr> <td>CT-1</td> <td></td> <td></td> </tr> <tr> <td>Stage 1</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> <tr> <td>Stage 2</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> <tr> <td>CT-2</td> <td></td> <td></td> </tr> <tr> <td>Stage 1</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> <tr> <td>Stage 2</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> <tr> <td>CT-3</td> <td></td> <td></td> </tr> <tr> <td>Stage 1</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> <tr> <td>Stage 2</td> <td><input type="text"/></td> <td><input type="text"/></td> </tr> </tbody> </table>		<u>ON (F)</u>	<u>OFF (F)</u>	CT-1			Stage 1	<input type="text"/>	<input type="text"/>	Stage 2	<input type="text"/>	<input type="text"/>	CT-2			Stage 1	<input type="text"/>	<input type="text"/>	Stage 2	<input type="text"/>	<input type="text"/>	CT-3			Stage 1	<input type="text"/>	<input type="text"/>	Stage 2	<input type="text"/>	<input type="text"/>	
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<p><u>CT Vibration Alarm.</u></p> <p>Jump the vibration sensor to simulate a vibration alarm.</p> <p><u>CT-1:</u></p> <p><u>CT-2:</u></p> <p><u>CT-3:</u></p>	<p>Observe that an alarm is registered and that the CT fan shuts off.</p>																																								

Prefunctional Checklist

Project _____

PC-01_____ CHILLED WATER PIPING_____

Components Included: All valves, except coil valves**Associated checklists:** Chiller, Cooling Tower, CDW Piping, CHW & CDW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative DateNotes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data							
Flushing and cleaning plan							
O&M manuals							

- Documentation complete as per contract documents for given trade YES NO

3. Physical Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Y / N	Contr.
Piping		
Pipe fittings complete and pipes properly supported		
Required seismic anchoring installed		
Pipes properly labeled		
Pipes properly insulated		
Strainers in place and clean		
Isolation valves and balancing valves installed		
Test ports (P/T) installed near all control sensors and as per spec		
Flushing and cleaning plan submitted and approved		
Piping system properly flushed and cleaned and temporary piping removed (report attached)		
Piping pressure tested according to contract documents (report attached)		
Chemical treatment system or plan installed		
Water treatment report submitted according to contract documents		
No leaking apparent around fittings		
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank		
Expansion tanks verified to not be air bound and system completely full of water		
Air vents and bleeds at high points of systems functional		
Valves (except coil valve checklists are with the unit checklist)		
Valve labels permanently affixed		
Valves installed in proper direction		

Notes:

Check	Y / N	Contr.
No leaks		
Valves stroke fully and easily and spanning is calibrated (see Section 5.2 below)		
Valves that require a positive shut-off are verified to not be leaking when closed at normal operating pressure		
Sensors and Gages		
Temperature, pressure and flow gages and sensors installed		
Sensors calibrated (See calibration section below)		
TAB		
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents		

- **The checklist items of Part 3 are all successfully completed for given trade.**___ YES ___ NO

4. Sensor Calibration

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors are calibrated within required tolerances**.....___ YES ___ NO

Notes:

5. Misc. Procedures (As referenced above)

5.1. Sensor Calibration Methods

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

5.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override valves or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

5.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

— END OF CHECKLIST —

Notes:

Prefunctional Checklist

Project _____

PC-06___ COMPUTER ROOM AC UNIT (Inside Section)

ID#'s _____

Components included: ___ Coils ___ Valves (CHW)**Associated Checklists:** ___ Outdoor condenser/compressor

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ___ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative DateNotes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- Documentation complete as per contract documents for given trade ☐ YES ☐ NO

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Volts/Ph/A 2						
3						
1						
Humidifier 2						
3						
1						
Reheat 2						
3						

- The equipment installed matches the specifications for given trade..... ☐ YES ☐ NO

4. Physical Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Cabinet and General Installation							
Permanent labels affixed, including for fans							
Casing condition good: no dents, leaks, door gaskets installed							
Boot between duct and unit tight and in good condition							
Vibration isolation equipment installed & released from shipping locks							
Maintenance access acceptable for unit and components							

Notes:

COMPUTER ROOM AIR CONDITIONING UNIT PREFUNCTIONAL CHECKLIST
PC-06

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Thermal insulation properly installed and according to specification							
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)							
Clean up of equipment completed per contract documents							
Filters installed and replacement type and efficiency permanently affixed to housing							
Reheat coil installed, if specified							
Humidifier coil installed, if specified							
Valves, Piping and Coils							
Pipe fittings complete and pipes properly supported							
Pipes properly labeled							
Pipes properly insulated							
Piping system properly flushed							
No leaking apparent around fittings							
All coils are clean and fins are in good condition							
All condensate drain pans clean and slope to drain, per spec							
Specified valves installed and properly labeled							
Valves installed in proper direction							
Valves stroke fully and easily and spanning is calibrated (see Section 7 below)							
Valves verified to not be leaking through coils when closed at normal operating pressure (see Section 7 below)							
OSAT, MAT, SAT, RAT, chilled water supply sensors properly located and secure (related OSAT sensor shielded)							
Sensors calibrated (See calibration section below)							
P/T plugs and isolation valves installed per drawings							
Fans and Dampers							
Supply fan belt tension & condition good							
Supply fan protective shrouds for belts in place and secure							
Supply fan area clean							
Supply fan and motor properly lubricated							
Filters clean and tight fitting							
No unusual noise or vibration							
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)							
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated (follow procedure similar to valves Section 7.3 below)							
All dampers close tightly							

Notes:

COMPUTER ROOM AIR CONDITIONING UNIT PREFUNCTIONAL CHECKLIST
PC-06

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
All damper linkages have minimum play							
Outside air capability to space installed							
Ducts (preliminary check)							
Sound attenuators installed							
Duct joint sealant properly installed							
No apparent severe duct restrictions							
Turning vanes in square elbows as per drawings							
OSA intakes located away from pollutant sources & exhaust outlets							
Pressure leakage tests completed							
Branch duct control dampers operable							
Electrical and Controls							
Pilot lights are functioning							
Power disconnects in place and labeled							
All electric connections tight							
Proper grounding installed for components and unit							
Safeties in place and operable							
Current overload heaters installed and correct size							
Sensors calibrated (see section below)							
Control system interlocks hooked up and functional							
Smoke detectors in place							
Enthalpy control and sensor properly installed (if applicable)							
Related thermostats are installed							
Related building automation system points are installed, including high temperature alarm and emergency power							
All control devices, pneumatic tubing and wiring complete							
TAB							
Installation of system and balancing devices allowed balancing to be completed per specified NEBB or AABC procedures & contract docs							
Final							
Startup report completed with this checklist attached							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
Functional test procedures for this equipment reviewed and approved by installing contractor							

Notes:

COMPUTER ROOM AIR CONDITIONING UNIT PREFUNCTIONAL CHECKLIST
PC-06_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.

- **The checklist items of Part 4 are all successfully completed for given trade.**___ YES ___ NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Supply fan rotation correct							
Fans > 5 Hp Phase Checks: (%Imbalance = 100 x (avg. - lowest) / avg.) Record all 3 voltages in cell. Imbalance less than 2%?							
Record full load running amps for each fan. _____ rated FL amps x _____ srvc factor = _____ (Max amps). Running less than max?							
Supply fan has no unusual noise or vibration							
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated (follow procedure similar to valves Section 7 below). List each actuated damper here when spanned:							
Valves stroke fully and easily and spanning is calibrated (see Section 7 below). List each actuated valve here when spanned:							
Valves verified to not be leaking through coils when closed at normal operating pressure (see Section 7 below)							
The HOA switch properly activates and deactivates the unit							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

- **The checklist items of Part 5 are all successfully completed for given trade.**___ YES ___ NO

6. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Notes:

COMPUTER ROOM AIR CONDITIONING UNIT PREFUNCTIONAL CHECKLIST
PC-06_____

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- ***All sensors are calibrated within required tolerances.....*** ☐ **YES** ☐ **NO**

Notes:

7. Misc. Procedures (as referenced above)**7.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

7.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST–

Notes:

Prefunctional Checklist

Project _____

PC-11__ BUILDING AUTOMATION SYSTEM

__ Entire Building

__ Only Floor or Zone _____

Associated checklists: _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. __ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Documentation submitted and approved:

[All]

☐ manufacturer's cut sheets
☐ installation and checkout manual and plan
☐ full written sequences and list of all control strategies
☐ written copy of all control parameters, settings and setpoints
☐ O&M manual | ☐ performance data
☐ operating manual
☐ completed control drawings
☐ design criteria
☐ full descriptive points list |
|--|--|

- **Documentation complete as per contract documents.....** ☐ YES ☐ NO

3. Model verification

[Contr =]

	As Specified	As Submitted	As Installed
Manufacturer			
Model No.			
Serial No.	n/a	n/a	
CPU			
Monitor			
Other primary features:			

- **The equipment installed matches the specifications for given trade.....** ☐ YES ☐ NO

4. Initial Setup and Checkout

4.1. User Terminal Interface and Sub-Panel Checks

Check if Okay. Enter comment or note number if deficient.

Check	Y / N	Contr.
General appearance good, no apparent damage		
Equipment labels affixed		
Layout and location of control panels matches drawings		
Areas or equipment panels serve clear in control drawings		
Wiring labeled inside panels (to controlled components)		
Controlled components labeled/tagged		
BAS connection made to labeled terminal(s) as shown on drawings		
Shielded wiring used on electronic sensors		
110 volt AC power available to panel		
Psig compressed air available to panel (if applicable)		
Battery backup in place and operable		
Panels properly grounded		

Notes:

Check	Y / N	Contr.
Environmental conditions according to manufacturer's requirements		
Date and time correct		

- **The above setup and checkout was successfully completed for given trade**__ YES __ NO

4.2. Device and Point Checkout

[CC]

The following procedures are required to be performed and documented for each and every point in the control system. The following procedures are minimum requirements. The control contractor is encouraged to identify better and more comprehensive checkout procedures in their submitted plan. These procedures are not a substitute for the manufacturer's recommended start-up and checkout procedures, but are to be combined with them, as applicable. The documentation may be provided on the vendor's stock form, as long as all the information in the sample table below can be clearly documented on the form.

Similar checkout and calibration requirements are found on the equipment prefunctional checklists. Redundant documentation is not required. Cross reference, by name and form number, to other forms that contain documentation left blank on the current form.

Procedures

1. [Wire] Verify that the wiring is correct to each point.
2. [Actu] If the device is or has an actuator, verify full free movement through its full range.
3. [Addr] Verify that the software address is correct.
4. [Load] For devices with a controller, verify that current software program with proper setpoints has been downloaded.
5. [DevCal] Device stroke/range calibration. This applies to all controlled valves, dampers, fans, pumps, actuators, etc. Simulate maximum and minimum transmitter signal values and verify minimum and maximum controller output values and positively verify each and every control device minimum and maximum stroke and capacity range. Follow procedure 6.2 below.
6. [SensLoc] Verify that all sensor locations are appropriate and away from causes of erratic operation.
7. [SensCal] Sensor calibration. Calibrate or verify calibration of all sensors and thermostats, including temperature, pressure, flow, current, kW, rpm, Hertz, etc. Verify that the sensor readings in the control system are within the sensor accuracies specified in this section, using hand-held or other external measuring instruments. Follow procedure 6.1 below.
8. [OperCk] For controlled devices (dampers, valves, actuators, VAV boxes, etc.), after mechanical equipment control becomes operational, perform an operational test of each control loop. Follow procedure 6.2 below. Operational checks are preparatory to the later *functional testing*.

Other Abbreviations:

- [BAS] Building automation system or gage-read value.
 [Instru]..... Instrument (calibrated) read value.
 [Offset]..... Offset programmed into the point to correct the calibration.

Notes:

Controls Checkout Documentation Table –SAMPLE FORM–

Point ID	Object	Field Device Type	Hardware Checks			Load	Dev Cal	Sens Loc	SensCal			Final Check	
			Wire	Actu	Addr				BAS	Instru	Offset	Oper Ck	
			1	2	3	4	5	6	7	7	7	8	9
AI-1	ZN-T (zone T)	PhJack	√	na	√	na	na	√	70.2F	71.4F	+1.2F	na	
3-2a	RA-DPR (damper)	PNEU	√	√	√	na	√	na	na	na	na	√	

- *The initial setup and checkout has been successfully completed as described in Section 4.2 and Section 6 and documented on attached forms YES NO*

5. Pneumatic System Pressure Test

[]

The entire pneumatic system servicing the controls shall be pressure tested as follows:

- 5.1. Test the high pressure air piping at [150 psi]. Maintain the pressure for 2 hours without loss of pressure. Correct and retest the system if any loss of pressure is indicated. Pass? (Y/N)_____
- 5.2. Test the low pressure control tubing at [30 psi]. Maintain pressure for 2 hours without pumping. If the pressure drops more than 1 psi, correct leak and retest until successful. Pass? (Y/N)_____

- *The pneumatic system pressure tests were successfully completed YES NO*

6. Misc. Procedures (Referenced above)

[CC]

6.1. Sensor Calibration Methods

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or

Notes:

building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.

- C. Water and Air Flow Verifications. ___Water, ___Air flow sensor read out at the BAS will be verified by a separate test instrument, unless calibration data on the permanent device is provided.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

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

6.2 Valve Stroke Setup Calibration and Check (Use an analogous procedure for dampers and vanes, motors, etc.)

Setup and Device Stroke Calibration. Check that valves are installed in the proper direction and that they are normally open or closed as specified. Command valve closed, sight-verify that valve is closed and adjust output zero signal as required. Command valve open, sight-verify that position is full open and adjust output signal as required. In both cases verify that BAS reading corresponds to sight-verified condition. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

Operational Checks.

For heating coil valves (NO): Set pumps to normal operating mode. Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. By override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal. In both conditions verify that BAS reading corresponds to site verified condition.

For cooling coil valves (NC): Set pumps to normal operating mode. Set cooling setpoint 20°F above room temperature. Observe the valve close. Remove control air from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set cooling setpoint to 20°F below room temperature. Observe valve open. By override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal. In both conditions verify that BAS reading corresponds to site verified condition.

For VAV Boxes (pressure independent): Start fans. Override space temperature to 55F, simulating full heating. Verify that BAS flow sensors read the maximum heating flow (cfm) and minimum cooling flow for that box, per box schedule. Verify proper opening of heating coil valve and operation of fan, if applicable. Override the space sensor to read 78F to simulate maximum cooling. Verify that BAS flow sensors read the maximum cooling flow (cfm) and minimum heating flow for that box, per box schedule. Verify proper closing of heating coil valve and operation of fan, if applicable. This verifies that the controlled devices are operating under normal control. Document this process on a written form with a cell for recording the check and calibration for each point. Investigate and report anomalies. This is done before balancing and is not a balancing procedure. Additional data may be recorded for each VAV box, such as box number, inlet size, etc.

- END OF CHECKLIST -

Notes:

Prefunctional Checklist

Project _____

PC-01_____ COOLING TOWER #'s _____

Associated checklists: Chiller, Chilled Water Piping, CHW Pumps, CDW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents.....** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						
1						
Motor Hp 2						
3						

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
Cooling tower in place and in good condition							
Fan belts adjusted							
Fan shaft collars installed and tight							
Fan lubricated							
Fan blade pitch adjusted (propeller fans only)							
Tower basin access in place							
Tower basin sump strainers clean and sump filled							
Sump heater and other freeze protection in place (alarms, tape)							
Temperature gauges installed							
Pressure gauges installed across circulating pump							

Notes:

COOLING TOWER PREFUNCTIONAL CHECKLIST

PC-01_____

Check if Okay. Enter comment or note number if deficient.

Spray water inlet strainer installed and clean						
Spray nozzles clean						
Electrical						
Power to unit and disconnect installed						
All electrical components grounded						
Power available to sump heater						
Motor protection and safeties installed						
Controls						
Sensors calibrated (see below)						
Control system interlocks hooked up and functional						
All control devices, pneumatic tubing and wiring complete						
Piping (Immediately around unit. Full piping in CHW Piping Checklist.)						
Pipe fittings and accessories complete						
Makeup water supply piped						
Makeup water shut-off valve installed						
Pipes are properly labeled (direction, etc.)						
Valves are properly tagged						
Chemical treatment system or plan installed						
Water treatment report submitted						
Distribution header balanced						
Test plugs installed						
Isolation and balancing valves installed per drawings						

• The checklist items of Part 4 are all successfully completed for given trade. YES NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Cooling tower starts and runs							
Fan rotation correct							

Notes:

COOLING TOWER PREFUNCTIONAL CHECKLIST

PC-01_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Measure line to line voltage phase imbalance for each fan: (%Imbalance = 100 x (avg. - lowest) / avg.) Record imbalance of each pump in cell. Imbalance less than 2%?							
Record full load running amps for each fan. _____rated FL amps x _____srtc factor = _____ (Max amps). Running less than max?							
Motorized valves, dampers and float switches functional							
No unusual noise or vibration							
After at least 24 hrs of operation, readjust belt tension							
Vibration alarm: Jump the vibration sensor to simulate an alarm. Verify fan shut down and BAS alarm.							
Verify sump heater operation, including staging.							
Test high and low water alarms.							
Specified point-to-point checks have been completed and documentation record submitted for this system							

- The checklist items of Part 5 are all successfully completed for given trade. YES NO

6. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Loc- ation OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Loc- ation OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- All sensors are calibrated within required tolerances..... YES NO

Notes:

7. Misc. Procedures (as referenced above)**7.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override valves or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

7.3 Valve Stroke Setup and Check

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

Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST –

Notes:

Prefunctional Checklist

Project _____

PC-_____ EXHAUST FANS ID #'s _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ____ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative DateNotes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents for given trade** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
CFM 2						
3						
Sound Pwr 1						
Level @ 63, 2						
250; 1K Hz 3						

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Cabinet and General Installation							
Permanent labels affixed							
Casing condition good: no dents, leaks, door gaskets installed							
Mountings checked and shipping bolts removed							
Vibration isolators installed							
Equipment guards installed							
Pulleys aligned							
Belt tension correct							
Plenums clear of debris							
Fans rotate freely							
Fire and balance dampers installed							

Notes:

EXHAUST FAN PREFUNCTIONAL CHECKLIST

PC-_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Backdraft dampers installed, per drawings, and operate freely							
Duct system complete							
Electrical							
Electrical connections complete							
Disconnect switch installed							
Overload heaters in place							
Control connections complete							
Operational Checks							
Fan rotation correct							
Electrical interlocks verified							
Any fan status indicators functioning							
No unusual vibration or and noise							
Record full load running amps for each fan. _____rated FL amps x _____srvc factor = _____ (Max amps). Running less than max?							
Check voltage: Rate = _____ Actual = _____ Within 5%?							
The disconnect switch properly operates							
After 24 hours of operation, recheck belt tension and alignment							

- The checklist items of Part 4 are all successfully completed for given trade. ___ YES ___ NO

– END OF CHECKLIST–

Notes:

Prefunctional Checklist

Project _____

PC-07_____ FAN COIL UNIT, FCU-#'s _____

Components included: _____SF, _____ Coils, _____Valves (coil), _____, VFD _____Dampers
_____ Ducts

Associated Checklists: _____CHW, _____HW Piping, _____Boiler, _____DX Condenser

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative Date

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents for given trade** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->							
1							
Manuf. 2							
3							
1							
Model 2							
3							
Serial # 3							
Coil 1							
Capacity 2							
3							
Fan 1							
Capacity 2							
3							

- **The equipment installed matches the specifications for given trade** **YES** **NO**

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
Permanent labels affixed, including for fans							
Casing condition good: no dents, leaks, door gaskets installed							
Access doors close tightly - no leaks							
Boot between duct and unit tight and in good condition							
Vibration isolation equipment installed & released from shipping locks							
Maintenance access acceptable for unit and components							
Sound attenuation installed (wraps in clg. units, etc.)							
Thermal insulation properly installed and according to specification							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->							Contr.
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)								
Clean up of equipment completed per contract documents								
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed								
Valves, Piping and Coils								
Pipe fittings complete and pipes properly supported								
Pipes properly insulated								
Pipes properly labeled								
Strainers in place and clean								
Piping system properly flushed								
No leaking apparent around fittings								
All coils are clean and fins are in good condition								
All condensate drain pans clean and slope to drain, per spec								
Condensate line trap installed per mfr								
Valves properly tagged								
Valves installed in proper direction								
P/T plugs and isolation valves installed per drawings								
OSAT, SAT, RAT, water supply sensors properly located and secure								
Sensors calibrated (See calibration section below)								
Measures taken to deal with condensation, especially if fan will cycle. List:								
Fans and Dampers								
Fan and motor alignment appear correct								
Fan belt tension & condition good								
Fan protective shrouds for belts in place and secure								
Fan area clean								
Fan and motor properly lubricated								
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)								
All dampers close tightly and linkages have minimum play								
Other (list):								
Ducts (preliminary check)								
Sound attenuators installed								
Duct joint sealant properly installed								
No apparent severe duct restrictions								

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Turning vanes in square elbows as per drawings							
OSA Intakes located away from pollutant sources & exhaust outlets							
Pressure leakage tests completed							
Ducts cleaned as per specifications							
Balancing dampers installed as per drawings and TAB's site visit							
Outside air capability to space serviced by FCU installed							
Electrical and Controls							
Power disconnects in place and labeled							
All electric connections tight							
Proper grounding installed for components and unit							
Safeties in place and operable							
Sensors calibrated (see below)							
Control system interlocks hooked up and functional							
Smoke detectors in place							
All control devices, pneumatic tubing and wiring complete							

- The checklist items of Part 4 are all successfully completed for given trade. YES NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Fan rotation correct							
Fan has no unusual noise or vibration							
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated (follow procedure similar to valves Section 7 below). List each actuated damper here when spanned:							
Valves stroke fully and easily and spanning is calibrated (see Section 7 below). List each actuated valve here when spanned:							
Valves verified to not be leaking through coils when closed at normal operating pressure (see Section 7 below)							
The HOA switch properly activates and deactivates the unit							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

Notes:

- The checklist items of Part 5 are all successfully completed for given trade. YES NO

6. Sensor and Actuator Calibration

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- All sensors are calibrated within required tolerances..... YES NO

7. Misc. Procedures (Referenced above)

7.1. Sensor Calibration Methods

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

- Sensors Without Transmitters--Standard Application.** Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- Sensors With Transmitters--Standard Application.** Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- Critical Applications.** For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

Notes:

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. **Method 1--Water Temperature With 2-Way Valve.** Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. **Method 2--Air Temperature With 2 or 3-Way Valve.** Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- C. **Method 3 Coil Drain Down (not for 3-way valves).** Put systems in normal mode. If cooling coil valve, remove all call for cooling or if heating coil valve put system in full cooling. Close isolation valve on supply side of coil, open air bleed cap, open drain-down cock and drain water from coil. Water should stop draining, else there may be a leak through the control valve. Return all to normal when done.

7.3 Valve Stroke Setup and Check

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

Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). **For heating coil valves (NO):** Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

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

– END OF CHECKLIST–

Notes:

Prefunctional Checklist

Project _____

PC-02_____ HEATING WATER PIPING_____

Components included: All valves, except coil valves**Associated checklists:** Boiler, HW Pumps

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. _____ List attached.

Mechanical Contractor Date_____
Controls Contractor Date_____
Electrical Contractor Date_____
Sheet Metal Contractor Date_____
TAB Contractor Date_____
General Contractor Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, _____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent Date_____
Owner's Representative DateNotes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data							
Flushing and cleaning plan							
O&M manuals							

- Documentation complete as per contract documents for given trade YES NO

3. Physical Installation Checks

Check	Y / N	Contr.	Note
Piping			
Pipe fittings complete and pipes properly supported			
Seismic anchoring installed			
Pipes properly labeled			
Pipes properly insulated			
Strainers in place and clean			
Isolation valves and balancing valves installed			
Test ports (P/T) installed near all control sensors and as per spec			
Flushing and cleaning plan submitted and approved			
Piping system properly flushed and cleaned and temporary piping removed (report attached)			
Piping pressure tested according to contract documents (report attached)			
Chemical treatment system or plan installed			
Water treatment report submitted according to contract documents			
No leaking apparent around fittings			
ASME pressure vessel data sheet or certification tag posted and inspection complete for each expansion tank			
Expansion tanks verified to not be air bound and system completely full of water			
Air vents and bleeds at high points of systems functional			
Valves (except coil valve checklists are with the unit checklist)			
Valve labels permanently affixed			
Valves installed in proper direction			
No leaks			

Notes:

Check	Y / N	Contr.	Note
Valves stroke fully and easily and spanning is calibrated (see Section 5.2 below)			
Valves that require a positive shut-off are verified to not be leaking when closed at normal operating pressure			
Sensors and Gages			
Temperature, pressure and flow gages and sensors installed			
Sensors calibrated (See calibration section below)			
TAB			
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents			

- **The checklist items of Part 3 are all successfully completed for given trade.** ____ YES ____ NO

4. Sensor Calibration

[]

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N _____. Sensors installed *in* the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors are calibrated within required tolerances**..... ____ YES ____ NO

Notes:

5. Misc. Procedures (as referenced above)**5.1. Sensor Calibration Methods**

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

- A. Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- B. Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watthour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

5.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.

5.3 Valve Stroke Setup and Check

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

Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open.

Notes:

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

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

– END OF CHECKLIST –

Notes:

Prefunctional Checklist

Project _____

PC-04_____ PACKAGED DX AIR CONDITIONING or HEAT PUMP, ID _____

Components included: ___supply fans, ___return & exhaust fans, ___coils,
___valves, ___VFD, ___dampers, ___compressors, ___condensers

Associated Checklists: _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
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Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- Documentation complete as per contract documents for given trade ☐ YES ☐ NO

3. Model verification

1 = as specified, 2 = as submitted, 3 = as installed. Enter information and check if Okay. Enter note number if deficient.

Equip Tag--->					
Manuf. 1					
2					
3					
Model 1					
2					
3					
Serial # 3					
Cooling 1					
Capacity 2					
3					
S Fan 1					
Capacity 2					
3					
R/E Fan 1					
Capacity 2					
3					
VFD or 1					
Inlet vanes 2					
3					

- The equipment installed matches the specifications for given trade ☐ YES ☐ NO

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Cabinet and General Installation							
Permanent labels affixed, including for fans							
Casing condition good: no dents, leaks, door gaskets installed							
Access doors close tightly - no leaks							
Boot between duct and unit tight and in good condition							

Notes:

PACKAGED, AIR CONDITIONING OR HEAT PUMP UNIT PREFUNCTIONAL CHECKLIST
PC-04

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Vibration Isolation equipment installed & released from shipping locks							
Maintenance access acceptable for unit and components							
Sound attenuation installed							
Thermal Insulation properly installed and according to specification							
Instrumentation installed according to specification (thermometers, pressure gages, flow meters, etc.)							
Clean up of equipment completed per contract documents							
Filters installed and replacement type and efficiency permanently affixed to housing							
Piping and Coils							
No leaking apparent around refrigerant fittings							
All coils are clean and fins are in good condition							
All condensate drain pans clean and slope to drain per spec							
OSAT, MAT, SAT, RAT sensors properly located and secure (related OSAT sensor shielded)							
Sensors calibrated (See calibration section below)							
If split system, refrigerant piping in good condition and suction insulated							
P/T plugs and Isolation valves installed per drawings							
Fans and Dampers							
Supply fan and motor alignment appear correct							
Supply fan belt tension & condition good							
Supply fan protective shrouds for belts in place and secure							
Supply fan area clean							
Supply fan and motor properly lubricated							
Return/exhaust fan and motor aligned							
Return/exhaust fan belt tension & condition good							
Return/exhaust fan protective shrouds for belts in place and secure							
Return/exhaust fan area clean							
Return/exhaust fan and motor lube lines installed and lubed							
Filters installed and replacement type and efficiency permanently affixed to housing--construction filters removed							
Filter pressure differential measuring device installed and functional (magnahelic, inclined manometer, etc.)							
Smoke and fire dampers installed properly per contract docs (proper location, access doors, appropriate ratings verified)							
All dampers close tightly							
All damper linkages have minimum play							

Notes:

PACKAGED, AIR CONDITIONING OR HEAT PUMP UNIT PREFUNCTIONAL CHECKLIST
PC-04

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Low limit freeze stat sensor located to deal with stratification & bypass							
Motors: premium efficiency verified, if spec'd?							
Compressor and Condenser							
Refrigerant sight glass clear of bubbles (if OSAT > 70F)							
Moisture Indicator shows no moisture							
Correct oil level (check sight glass during operation)							
Compressors and piping were leak tested, as required							
Crankcase heater on when unit is off							
Condenser coils clean and in good condition (air cooled)							
Adequate clearance for airflow around condenser							
Ducts (preliminary check)							
Sound attenuators installed							
Duct joint sealant properly installed							
No apparent severe duct restrictions							
Turning vanes in square elbows as per drawings							
OSA intakes located away from pollutant sources & exhaust outlets							
Pressure leakage tests completed							
Branch duct control dampers operable							
Balancing dampers installed as per drawings and TAB's site visit							
Electrical and Controls							
Pilot lights are functioning							
Power disconnects in place and labeled							
All electric connections tight							
Proper grounding installed for components and unit							
Safeties in place and operable							
Current overload heaters installed and correct size							
Auxiliary heaters installed							
Sensors calibrated (see section below)							
All building control system interlocks hooked up with packaged controls and functional							
Fire and smoke detectors in place							
Enthalpy control and sensor properly installed (if applicable)							
Related thermostats are installed							
Related building automation system points are installed							
All control devices, pneumatic tubing and wiring complete							

Notes:

PACKAGED, AIR CONDITIONING OR HEAT PUMP UNIT PREFUNCTIONAL CHECKLIST
PC-04

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
VFD							
VFD powered (wired to controlled equipment)							
VFD interlocked to control system							
Static pressure or other controlling sensor properly located and per drawings and calibrated (see Section 6)							
Static pressure or other controlling sensor calibrated							
Drive location not subject to excessive temperatures							
Drive location not subject to excessive moisture or dirt							
Drive size matches motor size							
Internal setting designating the model is correct							
Motor FLA setting represents 100% to 105% of motor FLA rating							
Appropriate Volts vs Hz curve is being used							
Accel and decel times are around 10-50 seconds, except for special applications. Actual decel: _____, Accel: _____							
Lower frequency limit at 0 for VAV fans. Actual: _____							
Upper frequency limit set at 100%, unless explained otherwise							
Unit is programmed with full written programming record submitted							
RPM readout in BAS verified with VFD readout							
TAB							
Installation of system and balancing devices will allow balancing to be done per specified NEBB or AABC procedures & contract docs							
Final							
Smoke and fire dampers and unpowered TU's are open?							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							
Functional test procedures for this equipment reviewed and approved by installing contractor							
If unit is started and will be running during construction: have quality filters on RA grills, etc. to minimize dirt in the ductwork and coils and in any finished areas. Verify moisture migration is not a problem due to improper pressures between spaces.							

- **The checklist items of Part 4 are all successfully completed for given trade.** YES NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Supply fan rotation correct		1					
Return / exhaust fan rotation correct		2					
No unusual noise or vibration in supply and exhaust fans							

Notes:

PACKAGED, AIR CONDITIONING OR HEAT PUMP UNIT PREFUNCTIONAL CHECKLIST
PC-04_____

Condenser fan rotation correct (air cooled)						
Condenser fan acceptable noise and vibration (air cooled)						
Measure line to line voltage phase imbalance for 1/3 of the compressors: Compressor 1 Phase: (%Imbalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) Record in cell, all three phase voltages. Imbalance less than 2%?						
Compressor 2 Phase: (%Imbalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) Record in cell, all three phase voltages. Imbalance less than 2%?						
Record full load running amps for each compressor. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?						
Record full load running amps for each condenser fan. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?						
Fans > 5 hp Phase Checks: (% Impalance = $100 \times (\text{avg.} - \text{lowest}) / \text{avg.}$) List fan & record all 3 voltages in cell. Imbalance less than 2%?						
Record full load running amps for each fan. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?						
Inlet vanes aligned in housing, actuator spanned, modulate smoothly and proportional to input signal and EMS readout.						
All dampers (OSA, RA, EA, etc.) stroke fully without binding and spans calibrated and BAS reading site verified (follow procedure similar to valves Section 7 below). List dampers checked: _____						
Valves stroke fully and easily and spanning is calibrated (see Section 7 below). List each actuated valve here when spanned: _____						
Valves verified to not be leaking through coils when closed at normal operating pressure (see Section 7 below)						
The HOA switch properly activates and deactivates the unit						
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent						
Specified sequences of operation and operating schedules have been implemented with all variations documented						
Specified point-to-point checks have been completed and documentation record submitted for this system						
Startup report completed with this checklist attached						

• **The checklist items of Part 5 are all successfully completed for given trade.**____ YES ____ NO

Notes:

6. Sensor Calibration

All field-installed temperature, relative humidity, CO, CO₂ and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. All test instruments shall have had a certified calibration within the last 12 months: Y/N_____. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. All actuators should also be calibrated, per the above checklist.

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

Sensor & Location	Location OK	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- All sensors and actuators are calibrated within required tolerances..... YES NO

7. Misc. Procedures (as referenced above)

7.1. Sensor Calibration Methods

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

- Sensors Without Transmitters--Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
- Sensors With Transmitters--Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

Notes:

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

7.2 Coil Valve Leak Check

- A. Method 1--Water Temperature With 2-Way Valve. Calibrate water temperature sensors on each side of coil to be within 0.5°F of each other. Turn off air handler fans and close OSA dampers. Make sure appropriate coil dampers are open. Normally closed valves will close. Override normally open valves to the closed position. After 10 minutes observe water delta T across coil. If it is greater than 2°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- B. Method 2--Air Temperature With 2 or 3-Way Valve. Calibrate air temperature sensors on each side of coil to be within 0.5°F of each other. Change mixed or discharge air setpoint, override values or bleed or squeeze bulb pneumatic controller to cause the valve to close. Air handler fans should be on. After 5 minutes observe air delta T across coil. If it is greater than 1°F, leakage is probably occurring. Reset valve stroke to close tighter. Repeat test until compliance.
- C. Method 3 Coil Drain Down (not for 3-way valves). Put systems in normal mode. If cooling coil valve, remove all call for cooling or if heating coil valve put system in full cooling. Close isolation valve on supply side of coil, open air bleed cap, open drain-down cock and drain water from coil. Water should stop draining, else there may be a leak through the control valve. Return all to normal when done.

7.3 Valve Stroke Setup and Check

For all valve and actuator positions checked, verify the actual position against the BAS readout. Set pumps to normal operating mode. Command valve closed, verify that valve is closed and adjust output zero signal as required. Command valve open, verify position is full open and adjust output signal as required. Command valve to a few intermediate positions. If actual valve position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics). For heating coil valves (NO): Set heating setpoint 20°F above room temperature. Observe valve open. Remove control air or power from the valve and verify that the valve stem and actuator position do not change. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator pressure rating) and verify valve stem and actuator position does not change. Restore to normal.

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

-- END OF CHECKLIST--

Notes:

Prefunctional Checklist

Project _____

PC-_____ PUMP #'s _____

Included components: VFD's _____

Associated checklists: ___Chiller, Cooling Tower, CHW & CDW Piping, ___Boiler and HW Piping, ___Other _____

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ___ List attached.

_____	_____	_____	_____
Mechanical Contractor	Date	Controls Contractor	Date
_____	_____	_____	_____
Electrical Contractor	Date	Sheet Metal Contractor	Date
_____	_____	_____	_____
TAB Contractor	Date	General Contractor	Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ___ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____	_____	_____	_____
Commissioning Agent	Date	Owner's Representative	Date

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- **Documentation complete as per contract documents for given trade** **YES** **NO**

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag-->					
1					
Manuf. 2					
3					
1					
Model 2					
3					
Serial # 3					
1					
Volts/Ph/A 2					
3					
1					
RPM 2					
3					
1					
GPM 2					
3					
1					
Motor Hp 2					
3					
1					
Motor Effic 2					
3					
1					
Head 2					
3					

- **The equipment installed matches the specifications for given trade.....** **YES** **NO**

4. Physical Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
Label permanently affixed							

Notes:

PUMP PREFUNCTIONAL CHECKLIST

PC-_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->							Contr.
Pumps in place and properly grouted								
Vibration isolation devices installed and functional								
Factory alignment appears correct								
Field alignment, if required, completed								
Seismic anchoring installed								
Temperature, pressure and flow gages and sensors installed								
Pump lubricated								
Piping (immediately around pump, see full piping checklist)								
Pipe fittings complete and pipes properly supported								
Pipes properly labeled								
Pipes properly insulated								
Strainers in place and clean								
Piping system properly flushed								
Valves properly tagged								
Sensors calibrated (See calibration section below)								
Electrical and Controls								
Power disconnects in place and labeled								
All electric connections tight								
Proper grounding installed for components and unit								
Motor safeties in place and operable								
Control system interlocks hooked up and functional								
All control devices, pneumatic tubing and wiring complete								
VFD								
VFD powered (wired to controlled equipment)								
VFD interlocked to control system								
Pressure or other controlling sensor properly located and per drawings and calibrated								
Pressure or other controlling sensor calibrated								
Drive location not subject to excessive temperatures								
Drive location not subject to excessive moisture or dirt								
Drive size matches motor size								
Internal setting designating the model is correct								
Input of motor FLA represents 100% to 105% of motor FLA rating								
Appropriate Volts vs Hz curve is being used								
Accel and decel times are around 10-50 seconds, except for special applications. Actual decel = _____ Actual accel = _____								

Notes:

PUMP PREFUNCTIONAL CHECKLIST
PC-_____

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Lower frequency limit at 0 for VAV fans and around 10-30% for chilled water pumps. Actual = _____							
Upper frequency limit set at 100%, unless explained otherwise							
Unit is programmed with full written programming record on site							
TAB							
Installation of system and balancing devices allowed balancing to be completed following specified NEBB or AABC procedures and contract documents							
Final							
Startup report completed with this checklist attached							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							

● **The checklist items of Part 4 are all successfully completed for given trade.** ____ YES ____ NO

5. Operational Checks (These augment mfr's list. This is not the functional performance testing.)

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
The HOA switch properly activates and deactivates the unit							
Pump rotation verified correct							
No unusual noise or vibration							
No leaking apparent around fittings							
Measure line to line voltage phase imbalance for each pump: (%Imbalance = 100 x (avg. - lowest) / avg.) Record imbalance of each pump in cell. Imbalance less than 2%?							
Record full load running amps for each pump. _____ rated FL amps x _____ svc factor = _____ (Max amps). Running less than max?							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							

● **The checklist items of Part 5 are all successfully completed for given trade.** ____ YES ____ NO

Notes:

6. Sensor Calibration

[]

All field-installed temperature and pressure sensors and gages on this piece of equipment shall be calibrated using the methods described below. Sensors installed *in* the unit at the factory with calibration certification provided by manufacturer need not be field calibrated.

Calibrating instrument, air pressure: _____ Certified calibration within last 12 mo's.

Calibrating instrument, water pressure: _____ Certified calibration within last 12 mo's.

Calibrating instrument, temperature: _____ Certified calibration within last 12 mo's.

Sensor and Location	Gage or BAS Value	Meas'd Value	Pass? Y/N	If NO, Calib'd to Comply?	Sensor and Location	Gage or BAS Value	Tested Value	Pass? Y/N	If NO, Calib'd. to Comply?
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____

The Contractor's own sensor check-out sheets may be used in lieu of the above, if the same recording fields are included and the procedures below are followed.

- **All sensors are calibrated within required tolerances.....** ☐ YES ☐ NO

7. Misc. Procedures (as referenced above)**7.1. Sensor Calibration Methods**

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

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

Notes:

- B. Sensors With Transmitters--Standard Application.** Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Record all values and recalibrate controller as necessary to conform with specified control ramps, reset schedules, proportional relationship, reset relationship and P/I reaction. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
- C. Critical Applications.** For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watthour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

— END OF CHECKLIST —

Notes:

Plan and Documenting Requirements for Startup and Initial Checkout

Primary Equipment and Tag: _____

Component or Related Equipment Included: _____

Project: _____ Date: _____

The purpose of documenting the startup and checkout process is to ensure to the Owner that all recommended startup and initial checkout procedures are completed and that a written record of the work is generated.

PLAN and REQUIRED PROCEDURES:

1. The prefunctional checklists provided by _____ should be filled out and signed for the above primary and related equipment.
2. The manufacturer recommended field startup and checkout sheets should be fully filled out. These startup and checkout sheets _____ are attached, _____ are not attached.
3. On the manufacturer field startup and checkout sheets, the recommended ranges for readings taken shall be added to each reading field and an explanation given for any variances.
4. Additional documentation:

_____ Further documentation beyond the above is required as follows:

The attached pages have been copied from the _____ installation manuals submitted to _____. They have had paragraphs and sections identified and marked with a signature lines in the margins. Separately for each piece of equipment, during startup and checkout, the technician should check and date each check box and initial and date each line made for that purpose, signifying completion of the task. All readings and settings shall be recorded, not just checked. Provide clear, written notes at the bottom, margin or back-side of each page, as necessary. Written notes shall be provided for why an item was not done or does not apply. A signature and date of the startup technician shall be provided at the end of the startup and checkout documents. Other pages applicable to this piece of equipment in the installation manual or any other procedures completed should be added.

_____ No further documentation beyond the attached checklist and the manufacturer's installation and startup sheets are required:

This list of procedures does not constitute a recommendation of the full installation and startup procedures or release the installer from following all factory recommendations, the specifications, applicable codes and good practice. All stock startup record forms normally generated should be filled out and submitted.

All documentation should be submitted to _____ upon completion and is required prior to the execution of functional testing.

Check	Air Side	Heating Water	Chilled Water
Prior to plan, TAB contractor had planning meeting with controls contractor to discuss using BAS for TAB			
All field checkout sheets and logs provided as part of plan			
Final test report sheets to be used provided as part of plan			
Field and final test report sheets list each piece of equipment to be tested, adjusted and balanced with the data cells to be gathered for each			
Discussion of what notations and markings will be made on the duct and piping drawings.			
List of all air flow, water flow, sound level, system capacity and efficiency measurements to be performed and provide a description of specific test procedures, parameters, formulas and test instrument type to be used for the measurements. Sample forms have been included.			
Detailed step-by-step procedures for TAB work: terminal flow calibration (for each terminal type), diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, etc. Similar for water side.			
Details of how <i>total</i> flow will be determined (Air: sum of terminal flows via BAS calibrated readings or via hood read of all terminals, supply (SA) and return air (RA) pitot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic, etc.)			
Specific procedures that will ensure (and which can be verified) that both air and water side are operating at the lowest possible pressures.			
Outside air ventilation criteria under all conditions clearly understood by TAB contractor			
Details of if and how min. outside air cfm will be verified and set and for what level (total bldg, zone, etc.)			
Details of how building static and exhaust fan / relief damper capacity will be checked.			
The identification and types of measurement instruments to be used and their most recent calibration date			
Proposed selection points for sound measurements			
Details of any TAB work to be done in phases (by floor, etc.), or of areas to be built out later			
Details regarding specified deferred or seasonal TAB work			
Details of any specified false loading of systems to complete TAB work			
Details of all exhaust fan balancing and capacity verifications, including any required room pressure differentials.		na	na
Plan for hand-written field technician logs of discrepancies, deficient or uncompleted work by others, contract interpretation requests and lists of completed tests (scope and frequency)			
Plan for formal progress reports (scope and frequency)			
Plan for formal deficiency reports (scope, frequency and distribution)			

• **The checklist items of Part 2 are all successfully completed. YES ____ NO ____**

– END OF CHECKLIST–

Comments:

Prefunctional Checklist Approvals and Procedures

Project _____

PC-05 Terminal Units

Associated checklists _____

Contractor filling out this form _____

1. Submittal

* For the items assigned to the Contractor(s) signing below, the checklist items are complete as marked and ready for functional testing. The checklist items have been checked off only by parties having direct knowledge of the event.
*This checklist is submitted for approval for the TU list attached, subject to the attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon deficiency correction. None of the outstanding items preclude safe and reliable functional testing of other TU's.

Controls Contractor _____ Date _____

Sheet Metal Contractor _____ Date _____

General Contractor _____ Date _____

Mechanical Contractor _____ Date _____

2. Requested Documentation Submitted:

Document	Y/N	Contr.
Manufacturer's cut sheets		
Installation and checkout manual		
O&M manual		

Document	Y/N	Contr.
Completed control drawings		
Full written sequences of operation		
All control parameters, deadbands & setpoints		

Documentation complete as per contract documents..... YES NO

3. Checkout Record

Prefunctional checklist items are to be completed on each TU as part of startup & initial checkout, preparatory to functional testing. Further instructions and an explanation of each checklist item, by column number, are found below. See attached sheets for actual checkout record. This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report. The installing contractor's startup and checkout plan shall make reference to incorporating this checklist or have it attached when submitting the plan to the commissioning agent for approval, prior to execution.

Col. # **CHECKOUT PROCEDURES AND KEY:** (refers to column number of TU record)

- Application and installation in conformance with mfrs recommendations and job specs. Specified sound wrapping and joint sealant installed.
- Any high pressure ducting upstream has been leak and pressure tested, cleaned and approved prior to setting TU.
- Model and tag checked against plans and equipment list. Tag or mark affixed.
- Unit secured per manufacturer's recommendations, contract documents and seismic requirements.
- Unit has sufficient clearance to be serviced.
- Inlet conditions OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor for flow readings and 3 to 5 diameters for single point electronic sensors, else airflow straighteners, OR per manufacturer's recommendation.
- All balancing devices have been provided in compliance with the contract documents.
- Any hot or chilled water piping installation complete with valves tagged. Auto-flow control valves checked to ensure proper model.
- Controls Hardware Check: a) Wiring checked to each point. b) Software pt. address input into box and checked for all points (zone temp. pressures for flow calcs, damper position, fan status, supply air temp., valve position, etc.). c) Release actuator clutch and verify free dam
- Controls Software Load. Power up unit and download approved software program.

Notes:

- 11 Operational Check. a) Start air handler fans. b) Override space temp. to be 55F to simulate full heating. Verify that BAS flow sensors read the maximum heating flow and minimum cooling flow for that box per box schedule. Verify proper opening of heating coil valve, if applicable. c) Override space temp. to be 80F to simulate full cooling. Verify that BAS flow sensors read the maximum cooling flow and minimum heating flow for that box per box schedule. Verify by observation, the proper closing of heating coil valve, if applicable. During the above sequencing, if box is fan powered, verify no unusual sound or vibration and verify proper fan staging.
- 12 Sensor Calibrations. All Sensors: a) Verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cable, are grounded only at one end. b) For sensor pairs that are used to determine temperature or pressure differences, make sure they are reading within 0.2F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Critical applications may be tighter. Sensor Without Transmitters: Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or BAS is within 0.5F for temps and within 3% of design for pressures of the instrument- measured value. If not, install an offset in the BAS, calibrate or replace sensor.
- ** Fully document procedures 9-12 on a separate form for each terminal unit. The form should have a cell to record each check and calibration for each sensor and BAS point, including max and min cfm's. Other data may also be included (inlet size, k factor, etc.). The above procedures are not a substitute for the manufacturer's recommended start-up and checkout procedures, but are to be combined with them , as applicable.
- 13 All A/E punch list items related to this TU have been corrected.
- 14 The system has been balanced in accordance with required procedures and the TAB has been approved for the AHU of this TU.
- 15 Required pipe cleaning to this unit, pipe flushing and pressure testing has been completed successfully.
- 16 Construction filter has been removed and final filter installed, if applicable.

3. Approvals

This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

Commissioning Agent

Date

Owner's Representative

Date

Notes:

PC-_____

[illegible]

Notes:

Prefunctional Checklist

Project _____

PC-_____ VARIABLE FREQUENCY DRIVE on

1. Submittal / Approvals

Submittal. The above equipment and systems integral to them are complete and ready for functional testing. The checklist items are complete and have been checked off only by parties having direct knowledge of the event, as marked below, respective to each responsible contractor. This prefunctional checklist is submitted for approval, subject to an attached list of outstanding items yet to be completed. A Statement of Correction will be submitted upon completion of any outstanding areas. None of the outstanding items preclude safe and reliable functional tests being performed. ____ List attached.

_____ Mechanical Contractor	_____ Date	_____ Controls Contractor	_____ Date
_____ Electrical Contractor	_____ Date	_____ Sheet Metal Contractor	_____ Date
_____ TAB Contractor	_____ Date	_____ General Contractor	_____ Date

Prefunctional checklist items are to be completed as part of startup & initial checkout, preparatory to functional testing.

- This checklist does not take the place of the manufacturer's recommended checkout and startup procedures or report.
- Items that do not apply shall be noted with the reasons on this form (N/A = not applicable, BO = by others).
- If this form is not used for documenting, one of similar rigor shall be used.
- Contractors assigned responsibility for sections of the checklist shall be responsible to see that checklist items by their subcontractors are completed and checked off.
- "Contr." column or abbreviations in brackets to the right of an item refer to the contractor responsible to verify completion of this item. A/E = architect/engineer, All = all contractors, CA = commissioning agent, CC = controls contractor, EC = electrical contractor, GC = general contractor, MC = mechanical contractor, SC = sheet metal contractor, TAB = test and balance contractor, ____ = _____.

Approvals. This filled-out checklist has been reviewed. Its completion is approved with the exceptions noted below.

_____ Commissioning Agent	_____ Date	_____ Owner's Representative	_____ Date
------------------------------	---------------	---------------------------------	---------------

Notes:

2. Requested documentation submitted

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Manufacturer's cut sheets							
Performance data (fan curves, coil data, etc.)							
Installation and startup manual and plan							
Sequences and control strategies							
O&M manuals							

- Documentation complete as per contract documents for given trade ☐ YES ☐ NO

3. Model verification

[Contr = _____]

1 = as specified, 2 = as submitted, 3 = as installed. Check if Okay. Enter note number if deficient.

Equip Tag--->						
1						
Manuf. 2						
3						
1						
Model 2						
3						
Serial # 3						
1						
Capacity 2						
3						

- The equipment installed matches the specifications for given trade..... ☐ YES ☐ NO

4. Installation Checks

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
General Installation							
Permanent label affixed							
Securely mounted							
Drive location not subject to excessive temperatures							
Drive location not subject to excessive moisture or dirt							
Drive size matches motor size							
Pilot lights functioning							
VFD wired to controlled equipment							
Programming and Controls							
Internal setting designating the model is correct							
Input of motor FLA represents 100% to 105% of motor FLA rating							
Appropriate Volts vs Hz curve is being used							

Notes:

Check if Okay. Enter comment or note number if deficient.

Check	Equip Tag->						Contr.
Accel and decel times are around 10-50 seconds, except for special applications. Record actual for each unit.							
Lower frequency limit at 0 for VAV fans and around 10-30% for chilled water pumps. Record actual for each unit.							
Upper frequency limit set at 100%, unless explained otherwise							
VFD interlocked to control system							
Static or differential pressure sensor or other controlling sensor properly located and per drawings							
Controlling sensor calibrated							
Unit is programmed with full written programming record submitted							
All control devices, pneumatic tubing and wiring complete							
Specified sequences of operation and operating schedules have been implemented with all variations documented							
Specified point-to-point checks have been completed and documentation record submitted for this system							
Final							
Startup report completed with this checklist attached							
Safeties installed and safe operating ranges for this equipment provided to the commissioning agent							

- The checklist items of Part 4 are all successfully completed for given trade. YES NO

-- END OF CHECKLIST --

Notes:

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15999

SAMPLE FUNCTIONAL TEST PROCEDURES

MECHANICAL

Spec writer:

The following example functional test procedures are provided for reference and do not necessarily reflect equipment or conditions in this project. The commissioning agent will write specific functional test procedures for this project.

SECTION 15999

SAMPLE FUNCTIONAL TEST PROCEDURES

MECHANICAL

A. GENERAL

This section contains sample Functional performance Test procedures in a form format (FT).

The sample FT procedures displayed in a form format here, are to provide contractors and CA with an example of a format and an indication of the rigor of the required testing and documentation for various equipment types. They were not developed for this project. Other forms and formats are acceptable if they comply with the rigor, clarity and intent of all the commissioning specifications. The CA will use the functional testing requirements in Sections 15997 and 16997 and the testing protocols specified in Section 17100 for developing site-specific functional test procedures and forms for this project. For illustrative purposes, sequences of operation associated with a few pieces of the equipment for which tests are included are also provided.

B. SAMPLE FUNCTIONAL TESTS (Examples only, not for this project)

This guide specification section continues with functional tests for the following equipment. The tests are provided in electronic file format (Word 6.0 for Windows 3.1). The file name is at the bottom of each page. The file name extension “ft__” stands for Functional Test and the last digit is the version number. Any MS Excel spreadsheet files are noted with their usual .xls extension. Some of the equipment also has a file with full sequences of operation, for reference when viewing the test procedures, and to illustrate the desired rigor of sequences of operation.

Division 16 functional test examples are found in Section 16999.

SYSTEM

ELECTRONIC FILE NAME

Air handler unit (cooling only)	ahu_cool.ft_
Air compressor (smoke damper)	aircompr.ft_
Boiler (packaged for heating water)	boilerhw.ft_
Boiler system sequences	boilerseq.004
Boiler system (multiple HW)	boilersys.ft_
Cabinet unit heater	cabunhtr.ft_
Chiller system	chiller.ft_
Chiller system sequences	chiller.seq
Economizer (airside)	econtest.ft_
Fin tube radiator	fintube.ft_
Heating fan coil unit	htfcncoil.ft_
Packaged rooftop AC unit	pkg_rtu.ft_
Small service water circ. pump	smlcpump.ft_
Split air conditioner (small)	split_ac.ft_
Service water heater	srvc_wh.ft_
Terminal unit (with HW reheat, 1-duct)	tu_rehet.ft_
Terminal unit (cooling only 1-duct)	tu_clg.ft_
Terminal unit (dual duct VAV)	tu_ddvav.ft_
Terminal unit (dual duct fan series)	tu_ddfan.ft_
Unit heater	unit_htr.ft_
Variable speed drive (fan)	vfdfan.ft_
Variable speed drive (pump)	vfdpump.ft_

See section 16999 for functional tests of electrical equipment.

C. SUGGESTED NUMBERING KEY FOR COMMISSIONING PROCEDURES

The checklists, functional tests, documentation and training use the following identification numbering:

At the beginning of the identification number is a text abbreviation for the following:

Document or Event Abbreviations

DOC	= Documentation
PC	= Prefunctional Checklist
SP	= Startup Plan
SR	= Startup Report
FT	= Functional Test
R	= Review
TR	= Training Record

Numbering Key

FT-0102.3: The first four digits uniquely identify the piece of equipment to the component level. The first 2 digits are the System Type, the second 2 digits are an arbitrary component number (not necessarily the same as the specified ID number). The number after the decimal is the test number. For example, FT-0102.3 = Functional Test 3 of system Type 1, component number 2 (e.g., 0102.3 = Chiller #2, FT #3, because chillers are system Type 1). Other components

under chillers are: additional chillers, pumps, valves, piping, VFDs. The component number of 00 means “general” or “all” components, as with the entire system. All tests, procedures, trainings and records should have the same first 4 digits for any given equipment component.

Another example is TUs. If there was only 1 TU type, then tests would be numbered FT-0500.1, 0500.2, etc. If there were 2 types of TUs: FT-0501.1, 0501.2, etc and 0502.1, 0502.2, etc.

An *example* of the number system follows:

0100	Chilled Water System	0200	Boiler System
0101	Chiller 1	0201	Boiler 1
0102	Chiller 2	0202	Boiler 2
0103	Cooling tower 1	0203	Pump HWP-1
0104	Cooling tower 2	0204	Pump HWP-2
0105	Pump CHWP-1	0205	HW piping
0106	Pump CHWP-2	0206	Sensor calibration
0107	CHW piping		
0108	CDW piping		etc.
0109	Sensor calibration		

Numbers for Primary System Types and Components

Components are in parentheses.

- 01 Chilled water system (chillers, cooling towers, pumps, condensers, piping, valves)
- 02 Hot water system (boilers, hot water pumps, valves, piping)
- 03 Air handler units (SF, RF, coils, valves, VFD, ducts, dampers)
- 04 Packaged, AC or HP units (SF, RF, coils, valves, VFD, ducts, dampers, compressors, condensers)
- 05 Terminal units
- 06 Computer room AC units
- 07 Unit heaters or AC spot coolers
- 08 Heat exchangers
- 09 Service water system
- 10 Test and balance (TAB)
- 11 Building automation system (controls)
- 12 Lighting controls
- 13 Specialty fans
- 14 Fume hoods

END OF SECTION

Functional Test

Project: _____

FT-_____ SMOKE DAMPER AIR COMPRESSOR

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing: __ Smoke dampers
- b. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.

Controls Contractor Signature or Verbal

Date

- c. __ All A/E punchlist items for this equipment corrected.
- d. __ Safeties and operating ranges reviewed.
- e. __ Test requirements and sequences of operation attached.
- f. __ Schedules and setpoints attached.
- g. __ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- h. __ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- i. __ **Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:**

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Compr. ON pressure		
BAS alarm setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Compr. OFF pressure		

- 3. Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.
--NONE--

4. Device Calibration Checks.

Notes:

---NONE---

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

___ Unit mounted securely. ___ Unit accessible for servicing. ___ No unusual noise or vibration in fan.

___ Condensate accumulator or air drier functioning

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		Bleed off air from the system between the compressor and regulator until it reaches the setpoint (currently ON at _____ psi and OFF at _____ psi).	Compressor starts.	
2 Seq. 1		<u>Low Pressure Alarm.</u> Continue bleeding air until the pressure read by the gage is equal to the BAS alarm setpoint (currently _____ psi).	An alarm is registered in the BAS. All air handlers shut OFF.	
3 Seq. 1		Remove bleed.	Observe compressor build pressure to OFF setpoint, then shut OFF.	
4		TREND LOG. Temporarily change the BAS Low Pressure Alarm setpoint to be 4psi above the ON compressor setpoint so an alarm will be generated every time the compressor comes ON (actually it will alarm twice, once on the way down and once on the way up). Track this for 24 hours during a week day.	Determine the compressor cycling frequency and make recommendations as to adequacy of the current design.	
4	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes¹Sequences of operation specified in Contract Documents (attached).²Mode or function ID being tested, per testing requirements section of the project Specifications.³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.⁴Include tolerances for a passing condition.⁵Record any permanently changed parameter values and submit to Owner.**— END OF TEST —**Notes:

Functional Test

Project: _____

FT-03 _____ COOLING AIR HANDLING UNIT AHU _____

And Associated Equipment Including:

___ Return Fans, RF _____

___ Outside Air Handling Unit, AHU _____

Related Tests: _____

1. Participants

Party

Participation

_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Date of test _____

2. Prerequisite Checklist

a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:

___ Chilled Water System

___ Condenser water pumps

___ Connected Terminal Units

___ Chilled water piping and valves

___ Cooling towers

___ Variable speed drives for pumps

b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal

Date

c. ___ Piping system flushing complete and required reports approved.

d. ___ Water treatment system complete and operational.

e. ___ Vibration control report approved (if required).

Notes:

- f. ___ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
- g. ___ All A/E punchlist items for this equipment corrected.
- h. ___ These functional test procedures reviewed and approved by installing contractor.
- i. ___ Safeties and operating ranges reviewed.
- j. ___ Test requirements and sequences of operation attached.
- k. ___ Schedules and setpoints attached.
- l. ___ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
- m. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
- n. ___ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- o. ___ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Discharge air static pressure (SP)P		
Discharge air temp.		
Static P. reset schedule		
Discharge air reset schedule		
OSA CFM		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Bldg. static P.		
Dirty filter D.P.		

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Notes:

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
DAT					
RAT					
OSAT					

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
Disch. SP					

¹Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	Procedure / State	1st BAS Value	Site Observation	Final BAS Reading	Pass Y/N
Cooling coil valve (CCV) position or command and stroke*	1. Intermediate positions				
	2. Full open				
	3. Increase pressure (open)				
	4. Closed				
	5. Remove power or air (closed)				
Relief damper position **	1. Closed				
	2. Full open				
Mixed air damper position **	1. Closed				
	2. Full open				
Main OSA damper position**	1. Closed				
	2. Full open				
Min. OSA damper position**	1. Closed				
	2. Full open				

* Set pumps to normal mode. *Procedure 1.* Command valve to a few intermediate positions. Verify that readings in BAS reasonably correspond to the actual positions. For cooling coil valves (NC): *Procedure 2.* Lower space setpoint to 20F below space temperature. Verify BAS reading says CCV is 100% open. Visually verify valve is 100% open. *Procedure 3.* For pneumatic actuators, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal. *Procedure 4.* Set space setpoint to 20F above space temperature. Verify BAS reading says CCV is closed. Visually verify valve is closed. *Procedure 5.* Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change.

**1. Command damper closed and verify that damper is shut and BAS reads shut. 2. Do the same, commanding damper fully open.

Notes:

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

General Conditions of Test

Notes:

6. Functional Testing Record

Seq. ID From Specs ¹	Mode ID ²	Test Procedure ³ (including special conditions)	Expected Response ⁴	Pass Y/N	Note
1	FAN OFF	Standby Check. With Units Commanded off by BAS.	Verify by visual inspection that: Return Air Dampers in AHU 3&4 are Open Outside Air Dampers in AHU-3&4 are Closed Isolation Dampers on AHU-9&10 are Closed. Relief Dampers in RF-3 and RF-4 are Closed Cooling Coil Valves on Cooling Coils of AHU--3&4 are Closed		
1	UNIT STARTUP	With Units Commanded on by BAS	Supply Fan Isolation Dampers Open in AHU-3&4(Both Supply Fans in each Unit) Supply Fan start through VSDs Supply Fan Isolation Dampers in AHU 9&10 Open AHU-9&10 Fans Start RF-3&4 Isolation Dampers Open RF-3&4 Fans start through VSDs Exhaust Fans EF-5,6,7,8,9&12 start.		
2	RF VOLUME CONTROL	<p>1. Verify RF Volume, utilizing air flow meters in Return Fans RF3&4, Supply Fans in AHU-3&4 and Garage Exhaust Fan EF-1, and TAB established CFMs for Exhaust Fans EF--5,6,7,8,9,12, TAB established Fixed Differential, make the following calculation: Return Air Flow=$\frac{1}{2}${Supply Air Flow(AHU-3Flow+AHU-4 Flow) - EF5 Flow-EF6 Flow-EF7 Flow-EF8 Flow-EF9 Flow-EF-12 Flow--SF1 Flow-Fixed Differential}</p> <p>2. Trend Log RF3&4, AHU 3&4, and SF-1 air flow rates at 5 min. intervals. Command off EF-5,6,7,8,9 and 12 sequentially at 5 min. Intervals.</p>	<p>Verify that RF air flow meter readings correspond to calculation.</p> <p>Verify that RF air flow meter readings continue to correspond to calculation</p>		

Notes:

Seq. ID From Specs ¹	Mode ID ²	Test Procedure ³ (including special conditions)	Expected Response ⁴	Pass Y/N	Note
3	TEMPERATURE CONTROL--ECONOMIZER	1. Utilizing BAS, Record OSA Temp. and OSA Dewpoint. 2. Calculate Enthalpy of OSA. 3. Utilizing Enthalpy calculations, reset DAT setpoint such that Enthalpy of OSA is less than Enthalpy of Supply Air at revised conditions.	Outdoor Air Dampers and Return Air Dampers should modulate in sequence to maintain DAT setpoint. Cooling Coil Valves should be closed.		
3	TEMPERATURE CONTROL--ECONOMIZER	1. Utilizing Enthalpy calculations above, reset DAT setpoint such that the Enthalpy of Supply Air is less than that of OSA. 2. Return to normal operation. Utilizing BAS trend logging capabilities, record OSA temperature, Return Air Temperature, OSA Dewpoint, DAT setpoint and DAT at 15 min intervals for an 8 hr. period	OSA Dampers should close, Return Air Dampers should open, Chilled Water Coil Valves should modulate to maintain discharge Temp. Unit should attempt to utilize economizer cycle when possible for cooling.		
4	STATIC PRESSURE CONTROL	Disable Static Pressure Reset utilizing BAS Software. Adjust space temperature setpoint on significant quantity of zones to be well below observed reading.	Verify that VSD's modulate as required to maintain SP setpoint without hunting or overshooting setpoint		
4	HIGH STATIC PRESSURE ALARM AND SHUTDOWN	With units running at low flow condition, utilizing a squeeze bulb, simulate an increase in discharge air static pressure.	Verify that BAS indicates an alarm condition at 3.6" WG and shuts fans down at 4"WG		
4	STATIC PRESSURE RESET	1. For Perimeter Terminal Units on floors 9-16, Reset space temperature setpoints to be below space temperatures. Utilizing BAS trend logging capabilities, Record at 5 min. intervals, Discharge Air SP Spt, Perimeter TU Units in saturation. 2. Reset space temperature setpoints to be above space temperatures. Utilizing the same Trending as above, Record the same data points.	Verify that DA SP Spts increase by 0.10" WG at 5 min intervals until only one Perimeter TU remains in saturation. Verify that setpoints are met and maintained without excessive hunting. Verify that DA SP Spt decreases by 0.10"WG at 5 min intervals until one Perimeter TU reaches saturation.		

Notes:

Seq. ID From Specs ¹	Mode ID ²	Test Procedure ³ (including special conditions)	Expected Response ⁴	Pass Y/N	Not e
5	DISCHARGE TEMPERATURE RESET	<p>1. For Perimeter Terminal Units Floors 9-16, Reset space sensor setpoints to be above space temperatures. Utilizing BAS Trend Logging, at 6 min intervals, record DAT setpoint, DAT, and perimeter TU cooling Flow rates.</p> <p>2. For Perimeter Terminal Units Floors 9-16, Reset space sensor setpoints to be below space temperatures. Utilizing BAS Trend Logging, at 6 min intervals, record DAT setpoint, DAT, and perimeter TU cooling Flow rates.</p>	<p>Verify that Discharge Air Temperature Setpoint is reset upwards at 2 deg increments every 6 min to maintain design cooling CFM at 5 perimeter TUs to maintain design cooling CFM</p> <p>Verify that Discharge Air Temperature Setpoint is reset downwards at 2 deg increments every 6 min to reach design cooling CFM at only 5 perimeter TUs. Both should happen without excessive hunting.</p>		
6	SMOKE CONDITIONS	Interfacing with EC, simulate a fire mode with the Fire Alarm System	Verify that AHU System returns to FAN OFF Status., with OSA and Relief Dampers in a Closed Position.		
7	WARMUP CONTROL	Place Units BAS Control Mode into Warmup. Overwrite RAT Sensor Reading to be 65 Deg. F.	Verify that dampers assume a 100% Return Air Mode.		
7	WARMUP CONTROL	Place Units BAS Control Mode in Warmup. Overwrite RAT Sensor Reading to be 72 Deg. F.	Verify that unit returns to Normal Operation Mode		
11	FREEZE CONDITION	Overwrite Low Limit Detection Thermostat reading to be 38 Deg. F.	Verify that system alarms, fans stop, OSA Dampers close, Relief Dampers Close, and RA dampers open.		
13	RETURN FAN STATIC PRESSURE	With AHU Units 3&4 Units running at low air flow condition, Overwrite RF 3 or 4 return air fan Inlet SP to a reading below -1.5" W.G.	Verify that system alarms and that all Fans are shut down.		

Notes:

Seq. ID From Specs ¹	Mode ID ²	Test Procedure ³ (including special conditions)	Expected Response ⁴	Pass Y/N	Note
14	NIGHT PURGE	With Units in Night Low Limit Mode, Select a space temperature sensor at random and overwrite this value to be 82 Deg. F. Overwrite OSA temperature value to 63 Deg. F. Overwrite Relief Air Temp. Sensor to a value of 82 Deg. F., after 15 minutes, Overwrite Relief Air Temp Sensor to a Value of 75 Deg. F.	Verify that Unit Starts, Return Air Dampers Close, Heating Control Valves remain Closed, OSA Dampers open, flushing space with OSA, When Return Air Temperature reaches a value of 75 Deg. F., Purge Cycle should terminate,		
15	MANUAL SMOKE PRESSURIZ. SYSTEM	With Fire Alarm System in alarm, utilizing control panel in Fireman Control Center, select a floor and place floor into purge mode	Verify that Single Fan operates, Isolation dampers open only on selected Fans, Return Fans are off, Outside Air Handling Units are off, OSA dampers open, and return air dampers close.		
B1	MIN OSA UNIT FAN OFF	Command AHU-1&2 System off	Verify that AHU 9&10 isolation dampers are closed, and if OSA temperature is above 35 Deg. F, heating coil control valve is closed.		
B1	MIN OSA UNIT FAN OFF	Simulate a OSA temperature below 35 Deg. F.	Verify that heating coil control valve opens		
B2	MIN OSA UNIT TEMPERATURE CONTROL	Utilizing BAS software, reset discharge air setpoint to 80 Deg. F.	Verify that Face and Bypass Dampers and Heating Coil Control Valves modulate in sequence to maintain 80 Deg. F. Setpoint.		
B3	MIN OSA UNIT FREEZE CONDITION	Simulate a condition at low limit detection thermostat of below 40 Deg. F.	Verify that BAS system goes into alarm, AHU 7&8 Fans Shut Down, AHU-7&8 Isolation Dampers Close, and Heating Valve Opens.		
	ON-FLOOR RETURN FAN OPERATION	Place AHU-3&4 in normal operating mode	Verify that RAF 9-1,9-2,10-1,10-2,11-1,11-2,12-1,12-2,13-1,13-2,14-1,14-2,15-1,15-2 Start and Run		
	AHU FILTER DROP	Reset the Filter Differential Pressure to exceed the setting recommended by the filter manufacturer.	Verify that the BAS reports an alarm.		

Notes:

Seq. ID From Specs ¹	Mode ID ²	Test Procedure ³ (including special conditions)	Expected Response ⁴	Pass Y/N	Note
-	CHILLED WATER VALVE CLOSING EFFICIENCY	1. Utilizing BAS, place AHU Units in WARMUP Mode. 2. Manually close isolation Valve in Chilled Water Supply to AHU Coil. 3. Place thermometer in Chilled Water Return Piping adjacent to AHU. Record temp. at 1 min. intervals for 15 min. 4. Manually open isolation Valve in Chilled Water Supply to AHU Coil. 5. Repeat Step 3. 6. Graph Results on Temperature-Time Basis.	Chilled Water Return Temp. should approach RAT. If significant divergence is noted, review specified performance requirements of Chilled Water Control Valves.		
--	SUPPLY FAN ISOLATION DAMPER FUNCTION	Utilizing BAS, Command AHU-1, SF-1 into the off position	Verify that AHU-1, SF-1 Isolation Dampers Close.		
	REVIEW	Review schedules, current setpoints and sequences with Specification Section 15950-3.3A and Control Drawings prepared by CC	Submit approved differences to be incorporated into as-builts.		

Record Foot Notes¹Sequences of operation specified in Contract Documents (attached).²Mode or function ID being tested from testing requirements section of the project Specifications.³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.⁴Include tolerances for a passing condition.⁵Record any permanently changed parameter values and submit to Owner.**– END OF TEST –****Notes:**

Functional Performance Test

Air-Side Economizer

Date: _____

Building Name: _____ Testing Agent: _____

Address: _____

Phone: _____ Assisted by: _____

Equipment Name: _____

Manufacturer: _____

ECM No. _____ ECM Name: _____ New/Retrofit: _____

Unit ID	AHU ID	Size (tons)	Zone
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____

Documentation. Installation and user's manuals on site (Y / N)? _____

Installation. Note any anomalies about the installations.

Space and OSA temperature sensors have been calibrated *and* OSA sensor located in open air, shaded, but not enclosed (where there may be heat buildup from the sun). (Y / N)? _____

Control Sequence Tests.	Unit 1	Unit 2	Unit 3	Unit 4
-------------------------	--------	--------	--------	--------

General Information

1. What is current space temperature setpoint? Cooling: _____ Heating: _____
(enter: occupied / unoccupied)

2. Economizer Characteristics:

Sensor type: DB = dry bulb, dH = enthalpy

Integrated: (Y / N)

Controls: PK = packaged only, EMS = all control by

EMS, PK+ = settings by package; enabled by EMS:

Dampers: How many positions is the damper system capable of, including when OFF (step positions: closed, minimum and full open)? Enter two, three or infinite. _____

3. What type of building pressure relief is there? (FL = fixed link to OSA damper, BD = barometric RA damper, EF = exhaust fan) _____
4. What are the current economizer setpoints (changeover temperatures)?
 (If OSA is below this, econ. will open) Package setting: _____
 (PK+ types will have both settings) EMS enable pt.: _____

Mode 1. Test Damper Position in AHU OFF Status

1. Turn unit OFF.
2. Are dampers completely shut? OSA: _____
 Relief: _____
3. Is return damper at maximum open? _____

Does the system comply in this mode? _____

Mode 2. Test Damper Position With AHU in ON Status; Compressor (or coil valve) and Econ. OFF

1. Turn cooling setpoint to 85F.
 2. Turn heating setpoint to 60F.
 3. Turn unit ON.
4. Are dampers at a minimum? OSA: _____
 Relief: _____
5. Is return air damper at maximum open? _____

6. NO in either of the above two questions denotes noncompliance.

Does the system comply in this mode? _____

Mode 3. Test Dampers in First Stage of Cooling (Econ. ON, Compressor or coil valve ON or OFF)

1. Adjust economizer setpoint or EMS OSA temperature values so economizer will turn on if cooling is called for.

For DB economizers, OSA temp. must be, or be simulated to read by keyboard edit in EMS, below the economizer setpoint and above any DA low limit (usually ~55°F if used). If OSA is too hot or too cold and there is no EMS system, use a wet rag or hair blower on OSA sensor OR come back at a time when OSA is appropriate, OR use jumper method of testing, OR use "canned" automatic testing sequence in unit, if any. The last two methods give only a partial assurance that the economizer is functioning. For enthalpy type economizers, locate the enthalpy of the space air and the OSA on a psychometric chart. Simulate conditions for either so that the OSA has less enthalpy than the inside air or use alternate methods above.

Describe method used:

2. Adjust cooling setpoint or space temp. until setpoint is 1°F <i>below</i> space temp. for integrated economizers (deadband + 1° for integrated types).	Record:	_____	_____	_____	_____
3. Cooling set point:		_____	_____	_____	_____
4. OSA temperatures (actual or simulated, circle): DB:		_____	_____	_____	_____
(for enthalpy types) Wet bulb:		_____	_____	_____	_____
5. Space temperature (actual or simulated, circle): DB:		_____	_____	_____	_____
(for enthalpy types) Wet bulb:		_____	_____	_____	_____
6. Do dampers open properly?					
(Full open for dry bulb econ., partial for enthalpy type. If	OSA:	_____	_____	_____	_____
OSA is below a functioning DA low limit, OSA damper	Relief:	_____	_____	_____	_____
will not be full open. Integrated economizers may not open full or at all in cold weather)					
7. Is return air damper closing proportionately?		_____	_____	_____	_____
8. Any NO answers in the above two questions denote noncompliance.					
Does the system comply in this mode?		_____	_____	_____	_____

Mode 4. Test if Economizer Is Integrated (Economizer ON, Compressor (or coil valve) ON)

1. Continuing from Mode 3, did compressor come on? _____
(It is best if it doesn't)
 2. If compressor does not come on, lower cooling setpoint
2° at a time (or raise space temp.) until compressor comes on. (circle action taken)
 3. What is the temp. of the changed parameter? _____
 4. Do dampers stay open *and not* at min.? OSA: _____
(If Yes, its integrated) Relief: _____
Is RA proportionately *closed*? RA: _____
-
5. Any NO answers in the last question denote noncompliance.
Does the system comply in this mode? _____

Mode 5. Test if Dampers Go to Minimum When OSA is Above Economizer Setpoint

1. Return economizer settings to original, if changed.
2. For DB type, lower econ. setpoint or heat up OSA sensor, or simulate OSA in EMS, until the OSA is 1°F above the economizer setpoint or changeover temperature. For enthalpy types, change conditions so that the space enthalpy on the psychrometric chart is *lower* than the OSA enthalpy. If dampers don't close, increase OSA temp. until they do.

	Unit 1	Unit 2	Unit 3	Unit 4
3. Do dampers close to minimum? OSA: _____	_____	_____	_____	_____
Relief: _____	_____	_____	_____	_____
4. Does the RA damper open to maximum? _____	_____	_____	_____	_____
5. What are the OSA temperatures being used to cause damper closure (this may be a real or simulated value)? DB: _____	_____	_____	_____	_____
(for enthalpy types) Wet bulb: _____	_____	_____	_____	_____
6. Is the OSA DB temperature being used, within 2° of what the economizer setpoint said it should be? _____ (use psychometric chart and manufacture's specs for enthalpy types)	_____	_____	_____	_____
7. For DB types, is this OSA temperature between 2-5°F below space temp. setpoint? _____ (the economizer should be set so it will open only below an OSA temp. of between 2-5°F below space setpoint)	_____	_____	_____	_____
8. Any NO answers in the above five questions denote noncompliance. <i>Does the system comply in this mode?</i> _____	_____	_____	_____	_____

Mode 6. Test if Dampers Go to Min. When Mixed Air Temp. (MAT) is Below Min. Setting

1. Cool down MAT sensor, or simulate MAT in EMS, until it is below the MAT setting. (~45-55°F)				
2. Do dampers close to minimum? OSA: _____	_____	_____	_____	_____
Relief: _____	_____	_____	_____	_____
3. Does the RA damper open full? _____	_____	_____	_____	_____
4. What is the MAT temperature being used to cause damper closure (this may be a real or an EMS simulated value)? _____	_____	_____	_____	_____
5. Is the MAT temperature being used within 2° of what the specs say the setpoint temperature should be? _____	_____	_____	_____	_____
6. Any NO answers in the above three denote noncompliance. <i>Does the system comply in this mode?</i> _____	_____	_____	_____	_____

Restore all adjustments to their original settings, unless desired as a permanent change. Make a permanent mark on any economizer local controllers showing where the appropriate setting should be. Y / N _____

Abbreviations: SA = supply air, RA = return air, DA = discharge air, OSA = outside air, EMS = energy management system

Functional Test

Project: _____

FT-____ **CABINET UNIT HEATER CUH-1; 2**

Related Tests: Boilers

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
 Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing: ____ CHU-1; 2
- b. ____ Boilers 1; 2 have successfully completed functional testing.
- c. ____ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.

 Controls Contractor Signature or Verbal

 Date

- d. ____ All A/E punchlist items for this equipment corrected.
- e. ____ Safeties and operating ranges reviewed.
- f. ____ Test requirements and sequences of operation attached.
- g. ____ Schedules and setpoints attached.
- h. ____ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
- i. ____ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- j. ____ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- k. ____ **Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:**

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
CUH-1 ON setpoint		
CUH-1 OFF setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
CUH-2 ON setpoint		
CUH-2 OFF setpoint		

Notes:

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____).

Sensor & Location	Location OK ¹	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
CUH-1;2 stat temp.		Stat:		Stat:	

¹Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

—NONE—

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____
 ___ Unit mounted securely. ___ Unit accessible for servicing. ___ No unusual noise or vibration in fan.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		Adjust CUH-1 ON setpoint until it is 1F above the space temp.	CUH-1 ___ Fan starts. ___ Htg valve opens; ___ warm air delivered.	
		Adjust CUH-2 ON setpoint until it is 1F above the space temp.	CUH-2 ___ Fan starts. ___ Htg valve opens; ___ warm air delivered.	
		Adjust CUH-2 OFF setpoint until it is 1F below the space temp.	CUH-2 ___ Fan stops. ___ Htg valve closes.	
2 Seq. 1		Adjust CUH-1 OFF setpoint until it is 1F below the space temp.	CUH-1 ___ Fan stops. ___ Htg valve closes.	
3	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Chilled Water System Sequence of Operations

Original 10/2/96 Sequence 6, CHWST Reset Revised 11/2/96

Overview

The chiller system is comprised of three chillers: two larger centrifugals (CH-1 and 2) with good part load efficiency down to 25% and one reciprocating chiller (CH-3) about 1/3 the size of the centrifugals which has excellent part load efficiencies with eight stages of unloading.¹ There is no automatic chiller staging/selection optimization controls. The preferred sequence of chiller staging may vary by season. The primary pumps and condenser pumps run at constant flow. There is a secondary chilled water supply loop with variable speed drives on the pumps controlled from differential pressure, which is reset incrementally to operate at the lowest speed and pressure possible to satisfy the current load. There are three cooling towers, each assigned to one chiller. There is also a heat exchanger in the condenser water loop that rejects heat from ACU-1-10 and CRU-1, which requires the lead cooling tower to operate year-round. The building automation system (BAS) controls many of the chiller functions and setpoints and just enables others, and monitors a number of points through the chiller interface. BAS in brackets denotes where the BAS has control over the setting or parameter, rather than the local chiller packaged control panel.

¹ Including pump energy, at high loads (75% - 100% of chiller capacity) the centrifugals are more efficient, at 50% the centrifugals and reciprocating chillers are about equal and at 25% load the reciprocating chiller is more efficient. Since 25% load on the small CH-3 is expected to rarely be encountered for any period of time, CH-1 and 2 should primarily be used.

Chillers (CH-1, 2; 3)

1. Software [BAS] lead lag selector to allow any of the chillers to act as the lead machine.
2. Chiller will only be enabled to operate in AUTO upon the following conditions:
 - a) Chiller scheduled ON [by BAS]
 - b) OSAT > 56F [BAS]
 - c) There are no active alarms that initiate a shutdown (reported to BAS and chiller panel)
 - d) The chiller sump temperature is above its minimum [BAS and chiller panel]
 - e) There is a call for cooling [BAS]
 - f) Chilled and condenser water flows are verified [BAS and chiller panel]
3. Upon a call for cooling², the lead primary CHW pump starts and the pump status is confirmed ON via a current sensor in the BAS and flow is confirmed through a flow switch. Then the assigned lead chiller oil pump starts, then the lead condenser water pump starts and the pump status is confirmed ON via a current sensor in the BAS and flow is confirmed through a flow switch. There are 30-60 second delays between these pumps, per the chiller integral programmed settings (adjustable). The lead secondary CHWP then starts, ramping up from the minimum RPM of _____ via the variable frequency drive (VFD), [per BAS or VFD??]
- ² A call for cooling is when a cooling coil valve (CCV) on one of the ON AHU's (AHU 1, 2, 3 or 4) is at least 15% open for at least 10 minutes. It is noted that the chiller packaged controls designate a call for cooling to be when the CHWST Spt is xx degrees lower than actual CHWT. This is inactive by being set to 0.
4. The lead chiller then starts with the prerotation vanes closed, which begin to open (closed to full open in ~ 3 minutes and full open to closed in ~1 minute).

5. The chiller maintains the CHW supply temperature at the setpoint [BAS] which ranges from 42F to 48F, based on a reset schedule, by modulating chiller capacity. CH-1 and CH-2 utilize prerotation vanes for capacity control, while the reciprocating chiller, CH-3, utilizes 8 stages of unloading.
6. Chilled water supply temperature (CHWST) reset [BAS]. The CHWST will have a default of 44F. The chilled water temperature will be reset only when the secondary pumps' speeds are at their minimum (as described in sequence 33). This is because, lowering pump speed with the differential pressure reset strategy (sequence 33) will save more energy than resetting the chilled water temperature up, per ton of cooling. When the pump speed is at its minimum allowed, start the CHWST reset routine and continue it until one or more pumps are above their minimum speed, then hold the CHWST setpoint where it is until the pumps are at their minimums. Include a differential or time delay to prevent hunting. When enabled, the CHWST reset sequence is: when all CCV's are less than 90% open, the CHWST setpoint (SPt) is at its highest value of a proportional range (48F). When three or more CCVs are 90% or more open, the CHWS Spt is at its lowest value (42F).

7. The CHWST reset will not increase when the return air relative humidity rises above 50% [BAS].
8. Chiller Staging. [All in BAS] There is no automatic chiller staging/selection optimization controls. The first lag chiller will be called for whenever the secondary CHW flow exceeds the primary CHW flow for 20 minutes (adjustable) as determined by flow meters AND the lead chiller is 95% loaded (by % of rated current).¹ For reference, each secondary CHW pump is design rated at 765 gpm. After a call has been maintained for the 20 minutes, the first lag chiller and pump sequence start as described above for the lead chiller. The second lag chiller will start under the same conditions and sequences. Whenever a lag chiller starts, all running chillers load and unload as necessary to be running within 5% of the same % load (based on rated current).
¹This 95% load parameter will allow CH-3 to operate as the lead chiller, if desired, up to its full load before the much larger chillers (CH-1 and 2) start, since there is such a difference in primary CHW flow between CH-1 or 2 and CH-3, but no difference in the secondary CHW pump flows for the different chillers.
9. The last selected lag chiller and associated pumps stage OFF when the total primary CHW flow exceeds the total secondary CHW flow by the capacity (flow) of the last selected chiller's primary CHW pump for a 20 minute duration (adjustable).
10. All chillers and pumps will turn OFF when OSAT is < 55°F for _____ minutes [BAS], OR when all CCV's are less than 15% open for 10 minutes [BAS], OR when all air handlers are OFF [BAS], OR when an unoccupied schedule occurs (subject to night low limit conditions not being met) [BAS], OR when failure alarms are registered (BAS and chiller controls).

Misc. Chiller Features

11. Chillers will not cycle ON and OFF more than three times in a one hour period (chiller controls).
12. Alarm on chiller failure. Failure alarms must be manually reset. See other alarm modes in chiller operator's manual [alarms created by chiller controls, shutdown by chiller controls, message sent to BAS].
13. Demand limiting. [BAS] Demand limiting setpoint adjustment may be made through building automation system [BAS]. The demand limit (in sum of all chillers kW), when met will delay the start of the next chiller for one hour (adjustable). This sequence is different than the disabled stock sequence in the chiller packaged controls.
14. The BAS will monitor kW and calculate the load on the chiller using evaporator CHW flow and temperature differentials [BAS].
15. Provide emergency stop switch located adjacent to chiller room mandoor exit to stop all equipment in chiller room, except ventilation system. Ventilation fan to automatically operate on purge mode with activation of emergency stop switch.

Primary Chilled Water Pumps (CHWP 1, 2, 3 for CH-1 & 2 and CHWP 4; 5 for CH-3)

16. Each primary CHW pump is assigned to one chiller [BAS]. Lead primary CHW pump starts upon a call for cooling per above chiller sequences. Lag primary CHW pump starts upon a call for the lag chiller per above chiller sequences [BAS].
17. Primary CHW pumps to operate continuously when their associated chiller is running. Primary CHW pumps provide constant flow through the chiller according to the manufacturer's recommendations: 675 gpm for CH-1 and CH-2 and 180 gpm for CH-3. Check balancing report for finals.
18. A standby (redundant) primary CHW pump is provided for CH-1 and 2 together and can be operated as active pumps after opening manual valves. A standby primary CHW pump for CH-3 will automatically change over [detected by BAS and chiller controller; pump control by BAS].
19. a) CHWP 1, 2; 3: Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, chiller shuts down and lag chiller should start automatically to meet load [BAS].
b) CHWP 4; 5: Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, standby pump automatically starts [detected by BAS and chiller controller; pump control by BAS].

Chiller Condenser Water Pumps (CDP 1, 2, 3, 4; 5)

20. CD pumps CDP 1, 2, 3 for CH-1 and CH-2 and CDP 4, and 5 for CH-3 to operate continuously when their associated chiller is running. CD pumps provide constant flow through the chiller condenser according to the manufacturer's recommendations: 1350 gpm for CH-1 and CH-2 and 360 gpm for CH-3.
21. A standby (redundant) CD pump is provided for CH-1 and 2 together. The pumps can be operated as active pumps after opening manual valves. A standby pump is provided for CH-3 and will automatically changeover [BAS].
22. a) CDP 1, 2; 3 (CH-1; 2): Alarm on pump failure detected via a motor current switch and flow switch. Upon failure of lead pump, chiller shuts down and lag chiller should start automatically to meet

load [detected by BAS and chiller controller; pump control by BAS].

b) CDP 4; 5 (CH-3): Alarm on pump failure detected via a motor current switch and flow switch.

Upon failure of lead pump, standby pump automatically starts [detected by BAS and chiller controller; pump control by BAS].

Cooling Tower (CT-1, 2; 3)

21. Cooling towers operate with operation of their associated condenser water pump. With operation of a pump, open selected tower supply valve and allow tower temperature control to function [BAS].
22. Software selector to allow any tower to be the lead tower, second tower or third tower [BAS].
23. CT Sequences. [All BAS] The CT during the normal cooling season rejects heat from the chillers and returns as cool of water as possible to the chiller's condenser, down to 65°F. The CT will try and maintain a 65°F return temperature (ECDWT) by first modulating the normally open bypass valve, with no water going over the top of the tower. When the valve is full open AND the ECDWT is greater than the ECDWT setpoint (65°F), the bypass valve begins to close and the normally closed CT control valve associated with the respective CT and CDW pump, opens 100% and water goes over the respective CT. The bypass valve continues to modulate open to try and maintain the ECDWT setpoint without the CT fans. When the ECDWT reaches 69°F, the bypass valve will be fully closed and the pony motor CT fan turns ON. When the ECDWT reaches 73°F, the main CT fan turns ON. As the ECDWT decreases, the main fan turns OFF at 69°F and the pony motor fan turns OFF at ECDWT of 65°F. All parameters are adjustable. There is an eight minute delay between each stage.

ECDWT		
<u>Fan Spd</u>	<u>ON (°F)</u>	<u>OFF (°F)</u>
OFF	<69	---
(modulation of bypass valve)		
*Low	69	65
*High	73	69

* Bypass valve should be closed.

24. When a lag chiller comes on line, its condenser water pump and associated CT come on line [BAS].
25. A multiple position CT sump or basin level sensor provides the following information to the BAS:
 - a) High water alarm
 - b) Low water alarm
 - c) Open make up water valve
 - d) Closed make up water valve
 - e) System shutdown
 Alarm on heater stage failure detected via current sensing switch.
26. Cooling tower sump two stage heaters shall be controlled to maintain a sump temperature of 45°F with the following schedule [BAS]:

	<u>ON (°F)</u>	<u>OFF (°F)</u>
Stage 1	45	43
Stage 2	47	45

Each CT basin has a temperature sensor and separate??? heaters.

27. Cooling tower makeup valve (one for all three CT's) to maintain sump water level. Upon sensing a drop in water level, slowly open makeup valve in industrial cold water line [level sensor by BAS].

28. Alarm on pony and main motor upon motor failure detected via current sensing relay. Upon failure of fan motor, lag CT starts automatically [BAS].
29. Alarm on excessive vibration detected via vibration limit switch. Upon failure of fan, lag CT starts automatically [BAS].
30. The lead cooling tower operate during periods, when the chillers are OFF (even during winter) to maintain a heat rejection source for the heat exchanger HE-1, which serves approximately 40 tons of cooling from ACU-1 thru 10 and CRU-1. See sequences for CDP 6, 7, 8; 9.

Secondary Chilled Water Pumps (CHWP 6, 7; 8)

31. Software lead/lag function allows any of the secondary pumps to act as the lead pump [BAS].
32. Lead secondary CHW pump starts upon a call for cooling per above chiller sequences. Lag secondary CHW pump starts upon a call for the lag chiller per above chiller sequences [BAS].
33. Differential pressure control. [All BAS] The objective is to always have one CCV 80% open so the pumps operate at the lowest speed and pressure possible to satisfy the current load. Every 5 minutes the CCV's are polled. A PI loop that changes the secondary pump discharge differential pressure setpoint to maintain the remote (local on 8th floor) DP setpoint to maintain the most open CCV at 80% open (with a deadband of +/- _____). For example: When the most open CCV is more than 80% open, a PI signal is calculated and changes the local DP setpoint upward. When the local DP setpoint is not being met, a PI signal is calculated and sent to the pump discharge pressure setpoint and it is raised accordingly. Through another PI loop, the variable speed (frequency) drive (VFD) increases the pump motor speed to meet the raised pump differential (discharge) pressure setpoint.

The remote DP setpoint will be maintained between maximum and minimum pressures. The maximum pressure limit is the pressure required to provide full flow to all CCV's simultaneously (per TAB).

The minimum pressure limit is the pressure correlating to the lowest speed the pump motor is allowed to be operated at (per motor manuf. and TAB). Maximum pressure limit: _____ psi. Minimum pressure limit: _____ psi.

The VFD internal settings will allow the VFD to run the pumps to their minimums.

Number of remote DP sensors: _____. Locations: _____

34. Pump Staging. [BAS] With one secondary CHW pump running, when the total secondary CHW gpm exceeds the lead secondary CHW pump design gpm AND the discharge differential pressure drops more than 2 psi below the setpoint for 10 minutes (all adjustable), start the first lag pump. Both pumps converge and run at similar speeds and gpm to maintain the common discharge pressure differential setpoint and the remote DP setpoints. If the total secondary gpm exceeds the total design gpm of the running pumps (lead and 1st lag) AND the discharge differential pressure drops more than 2 psi below the setpoint for 10 minutes, start the second lag pump. All three pumps converge and run at similar speeds and gpm to maintain the common discharge pressure differential setpoint and the remote DP setpoints.
35. During reducing load as the DP increases: when the total secondary CHW gpm has reduced to be equal to or less than the sum of the first two selected pumps' gpm for 10 minutes (adjustable), the second lag secondary CHW pump shuts OFF. Similarly, when the total secondary CHW gpm, with two pumps ON, has reduced to be equal to or less than the gpm of the lead CHW pump for 10 minutes, the first lag pump shuts OFF.

36. The controller shall monitor rpm and gpm of the pumps and shall not allow operation of the pumps at or beyond their published "End of Curve" [BAS].
37. Alarm on pump failure detected via current sensing switch. Upon failure of pump, next lag pump starts automatically (BAS and chiller controller).
38. Alarm on failure of VFD [BAS].
39. The rpm of secondary CHW pumps to be monitored by BAS.
40. For coil freeze protection during smoke exhaust system operation, pumps CHWP-6, 7; 8 to run under NORMAL control and all cooling coil valves to open with operation of respective AHU when smoke exhaust system (EF-10) is in operation AND outside air temperature is below 40°F [BAS].

ACU Condenser Water Pumps (CDP 6, 7 and 8; 9) and HE-1

41. The lead cooling tower operates during periods, when the chillers are OFF (even during winter) to maintain a heat rejection source for the heat exchanger HE-1, which serves approximately 40 tons of cooling from ACU-1 thru 10 and CRU-1. CDP 6 or 7 (one is redundant) provides water from the heat exchanger to the cooling towers. CDP 8 or 9 (one is redundant) services the ACU's and CRU-1 from HE-1. The selected CD pump for each loop (CDP 6 or 7 AND 8 or 9) operate continuously [BAS].
42. During chiller OFF periods, the ECDWT setpoint and CT bypass valve and fan staging parameters remain the same as during chiller ON periods (see above).
43. Alarm on pump failure detected via current sensing switch. Upon failure of any pump, standby pump automatically starts [BAS].

General Chiller Operation During Unoccupied Periods

44. Unoccupied Operation. During scheduled unoccupied hours at night or weekends, the chiller system is in standby, except the cooling tower operates as required to maintain 65°F condenser water to the heat exchanger HE-1 for heat rejection of ACU-1 thru 10 and CRU-1.
45. Winter Operation. During winter, the chiller system is in standby, except the cooling tower operates as required to maintain 65°F condenser water to the heat exchanger HE-1 for heat rejection of ACU-1 thru 10 and CRU-1.

Functional Test

Project _____

FT-01-01 CHILLERS 1 thru 3

And Chiller System Including:

Cooling Towers 1 thru 3

CHW Pumps 1 thru 8, including variable speed drives

CD Pumps 1 thru 9 and Piping

HE-1 (heat exchanger)

Related Tests: _____

1. Participants

Party

Participation

_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____

Dates of tests _____

Dates of tests _____

Dates of tests _____

2. Test Prerequisites

a. ___ The following have been started up and startup reports* and prefunctional checklists submitted and approved ready for functional testing:

___ Chiller

___ Chilled water pumps

___ Cooling towers

___ Condenser water pumps

___ Chilled water piping and valves

___ Variable speed drives for pumps

*The written chiller startup report must contain a full listing of all adjustable internal program settings.

Notes:

- b. ☐ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

Controls Contractor Signature or Verbal

Date

- c. ☐ Piping system flushing complete and required report approved.
d. ☐ Water treatment system complete and operational.
e. ☐ Vibration control report approved (if required).
f. ☐ Test and balance (TAB) complete and approved for the hydronic system.
g. ☐ All A/E punchlist items for this equipment corrected.
h. ☐ These functional test procedures reviewed and approved by installing contractor.
i. ☐ Safeties and operating ranges reviewed.
j. ☐ Test requirements and sequences of operation attached.
k. ☐ Schedules and setpoints attached.
l. ☐ False loading equipment, system and procedures ready (cross-over piping, preheat or reheat coils, control loops, over-ride on OSA dampers, etc.)
m. ☐ Sufficient clearance around equipment for servicing.
n. ☐ Sump or crankcase heaters have been on long enough to allow immediate starting of chillers.
o. ☐ Have all energy savings control strategies, setpoints and schedules been incorporated that this chiller and control system are capable of? If not, list recommendations below.
p. ☐ **Control Program Review.** Review the software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.

Notes:

- q. ___ Record made of All Values for Current Setpoints (SPt), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accomodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Space Temp. Setpts		
Economizer damper and changeover settings		
Preheat coil valve (auto, manual)		
Min. OSA preheat coil DAT setpoint		
Boiler enable, heating water temp. etc.		
CHWS SPt temp		
Lead chiller ID: Lag 1 ID: Lag 2 ID:		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Primary CHW Pumps CHWP-1 CHWP-2 CHWP-3 CHWP-4 CHWP-5 (hand, off, auto)		
Manual piping & valving for standby PCHWP		
EF-10 (hand, off, auto)		
Secondary CHW Pumps CHWP-6 CHWP-7 CHWP-8 (hand, off, auto)		
Condenser Pumps CDP-1 CDP-2 CDP-3 CDP-4 CDP-5 CDP-6 CDP-7 CDP-8 CDP-9 (hand, off, auto)		
VFD CHWP-6 CHWP-7 CHWP-8 (hand, off, auto)		
Demand Limit CH-1: CH-2: CH-3:		

Notes:

Parameter	Pre-Test Values	Returned to Pre-Test Values √
Lead CD pump ID: Lag 1 ID: Lag 2 ID:		
Safety Overrides		
Lead CHW pump ID: Lag 1 ID: Lag 2 ID:		
Chillers CH-1: CH-2: CH-3: (hand, off, auto)		
Chiller flow switches CH-1: CH-2: CH-3: (normal, jumped)		
CHW diff. press. Spt Across pump: Out in system:		
Delays		

Parameter	Pre-Test Values	Returned to Pre-Test Values √
CT fans CT-1 CT-2 CT-3 (hand, off, auto)		
CT vibration sensors CT-1 CT-2 CT-3 (normal, jumped)		
CT sump overflow CT-1 CT-2 CT-3 (normal, plugged)		
CT makeup valve CT-1 CT-2 CT-3 (auto, manual)		
Occupied schedule Start Stop		

Notes:

3. Sensor Calibration Checks. The sensors listed below checked for calibration and adequate location. This is a spot check on a sample of the calibrations done during prefunctional checklisting.*

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements. If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Test instrument, air pressure: _____ Certified calibration within last 12 mo's.

Test instrument, water pressure: _____ Certified calibration within last 12 mo's.

Test instrument, temperature: _____ Certified calibration within last 12 mo's.

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
ECDWT					
Pump dP sensor					
CT-1 sump T.					

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instr. Meas'd Value	Final Gage or BAS Value	Pass Y/N?
CT-2 sump T.					
CHWST					

¹Sensor location is appropriate and away from causes of erratic operation.

*For every sensor originally found out of calibration, check one additional sensor not listed.

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.**

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	1st BAS Reading	Site Observation	Final BAS Reading	Pass Y/N
CHWP-6 rpm				
CHWP-7 rpm				
CHWP-8 rpm				

Device or Actuator & Location	1st BAS Reading	Site Observation	Final BAS Reading	Pass Y/N
CT-1 fan stage 1				
CT-1 fan stage 2				
CT-2 fan stage 1				
CT-2 fan stage 2				
CT-3 fan stage 1				

Notes:

Device or Actuator & Location	1st BAS Reading	Site Observation	Final BAS Reading	Pass Y/N

Device or Actuator & Location	1st BAS Reading	Site Observation	Final BAS Reading	Pass Y/N
CT Bypass valve				

**For every actuator or device originally found out of calibration, check one additional one not listed.

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

V. Notes on Methods Used to False Load Chiller (for reference, see Note 6 at end of test)

6. Seasonal Testing and General Conditions of Test

Due to the building completion being during winter, this test will be completed in two stages. The first testing will occur prior to substantial completion, during cold weather. The objective of this first stage test is to provide reasonable assurance that the chiller will function properly during lower load conditions. This will prepare the chiller for operation during the beginning of the cooling season. As many of the test procedures as possible will be executed during this first test, through the use of the methods of false loading noted above and in Note 6 at the end of the test. Tests of all chillers close to full load and full cooling tower fan staging will not be able to be executed until summer. Chiller safeties will be tested prior to occupancy and cooling tower winter operation and sump heater tests will be performed during cold weather of the first test.

At the beginning of the cooling season, the chiller will be started and operated, without further testing, unless problems arise. Then, when conditions are warmer (approximately 80F-85F), the second test will be performed. This will likely require some false loading to create close to full load conditions and subsequently may need to be

Notes:

executed on a weekend to minimize discomfort to occupants. During this second test, some of the sequences performed during the first test will be retested and recorded, as necessary, to get to the staging and full load tests not performed during the first test. Also, the benchmarking and trending will be completed during the second test period.

7. Test Procedure Table of Contents

	<u>Procedure #</u>
Chiller system (including cooling tower) startup and staging ON and OFF (with lead chiller)	1-8, 14
Chiller system staging with lag chiller	1b-8b (after 56)
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Variable speed drives and CHWP6, 7; 8.....	11-14
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CHW supply reset	28-29
CHW pressure control	30-32
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Reciprocating chiller staging (CH-3)	34
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Notes:

8. Testing Procedures and Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																												
CHILLER SYSTEM STARTUP AND STAGING																																	
1 Seq 1- 4, 16, 20-23, 32	Specs 15682 3.3.; 15683 3.2	<p><u>Startup Sequence.</u> Lead = CH-____. (This is not the <u>initial</u> startup by factory reps). With chiller system off, with schedule allowing chillers ON and OSAT >56F, turn chillers and pumps to auto. Turn on AHUs and cause a call for cooling sufficient to call for chillers (see manually open preheat coil valve, lower space temperature SPt, etc. A call for the chillers will be made when any AHU fan is ON and its CCV is => 15% open for 10minutes.</p> <p><u>Vanes:</u></p> <p><u>Cooling Tower:</u> Specified Sequences:</p> <p style="text-align: center;">ECDWT</p> <table border="1"> <thead> <tr> <th>Fan Spd</th> <th>ON (F)</th> <th>OFF (F)</th> </tr> </thead> <tbody> <tr> <td>OFF (modulate bypass valve)</td> <td><69</td> <td>---</td> </tr> <tr> <td>*Low</td> <td>69</td> <td>65</td> </tr> <tr> <td>*High</td> <td>73</td> <td>69</td> </tr> </tbody> </table> <p>* Bypass valve should be closed. Eight minute delay between stages.</p>	Fan Spd	ON (F)	OFF (F)	OFF (modulate bypass valve)	<69	---	*Low	69	65	*High	73	69	<p>Observe that the lead primary CHW pump does not turn ON until a CCV on an ON AHU is => 15% [_____] open for 10 min. [____].</p> <p>Observe lead secondary CHW pump start when a CCV is 15% [____] open for 10 [____] minutes.</p> <p>Observe CHW primary and secondary pumps turning on, then the oil pump; then the CD pump (30-60s delay ea.)</p> <p>Observe that secondary pumps start at minimum RPM and slowly ramp up. Starting RPM = [____].</p> <p>Observe the lead chiller starting. Observe that the vanes start closed and begin to open. (max spd = 0-full open in ~3 min. and closed in ~1 minute)</p> <p>OSAT = [____] F.</p> <p>Observe that when the lead chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps during lead chiller operation only: [____], [____], [____], [____], [____].</p> <p>Record of Observed Sequences:</p> <table border="1"> <thead> <tr> <th>Fan Spd</th> <th>ECDWT ON (F)</th> <th>OFF (F)</th> <th>Delay (min)</th> </tr> </thead> <tbody> <tr> <td>OFF (bypass valve modulating)</td> <td>[____]</td> <td>---</td> <td></td> </tr> <tr> <td>Low</td> <td>[____]</td> <td>[____]</td> <td>[____]</td> </tr> <tr> <td>High</td> <td>[____]</td> <td>[____]</td> <td>[____]</td> </tr> </tbody> </table>	Fan Spd	ECDWT ON (F)	OFF (F)	Delay (min)	OFF (bypass valve modulating)	[____]	---		Low	[____]	[____]	[____]	High	[____]	[____]	[____]		
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Low	[____]	[____]	[____]																														
High	[____]	[____]	[____]																														
	15682 3.3.E	Maintain chiller load between 10-15% for 30 minutes.	Observe that there is no surging or abnormal vibration.																														

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																								
2 Seq 8	Specs 15682 3.3.; 15683 3.2	<u>1st Lag Chiller Staging ON.</u> Staging sequence: CH-____-->CH-____ With chillers in auto, and loaded such that only lead chiller is running, lower space setpoints so CCVs open. Wait ~10 minutes. Record time that primary flow and secondary flow become equal. Wait 20 minutes.	Total primary flow = [_____] gpm]. Secondary CHW flow => primary CHW flow = [_____] gpm] and lead chiller is at least 95% loaded (by % of rated current), [_____] amps]. Time: [_____] . After 20 minutes, 1st lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 1st lag chiller started = [_____] . Observe that the amps on both chillers are within 5% of each other.																										
3 Seq 8; 32-34	Specs 15683 3.3.F. 2	<u>1st Lag Secondary CHWP Staging ON.</u> Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____] gpm, [_____] rpm] > total design flow of ON SCHW pumps (765 gpm), and the SCHW pump dP drops 2 psi [_____] below SPt for 10 minutes, the first lag SCHWP turns ON. Observe that the 2 pumps' rpm are aprox. equal and at aprox. 50% (880 rpm), [CHWP-_____] rpm, CHWP-_____] rpm] and that total flow is just over previous gpm (765) [_____] gpm], and that after ~ 2 minutes, pump dP is maintained at SPt [_____] [_____] and remote dP is maintained at SPt [_____] [_____] .																										
4 Seq 8; 21-24	Specs 15682 3.3.; 15683 3.2	<u>1st Lag Cooling Tower Staging ON.</u> During the preceding sequences:	OSAT = [_____] F]. Observe that when the 1st lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when both chillers are operating: [_____] , [_____] , [_____] , [_____] , [_____] . Record of Observed Sequences: <table><tr><th>Fan Spd</th><th colspan="2">ECDWT</th><th>Delay</th></tr><tr><th></th><th>ON (F)</th><th>OFF (F)</th><th>(min)</th></tr><tr><td>OFF</td><td>[_____] </td><td>---</td><td></td></tr><tr><td colspan="4">(bypass valve modulating)</td></tr><tr><td>Low</td><td>[_____] </td><td>[_____] </td><td>[_____] </td></tr><tr><td>High</td><td>[_____] </td><td>[_____] </td><td>[_____] </td></tr></table>	Fan Spd	ECDWT		Delay		ON (F)	OFF (F)	(min)	OFF	[_____]	---		(bypass valve modulating)				Low	[_____]	[_____]	[_____]	High	[_____]	[_____]	[_____]		
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High	[_____]	[_____]	[_____]																										

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
5 Seq 8	Specs 15682 3.3.; 15683 3.2	<u>2nd Lag Chiller Staging ON Cont.</u> After second chiller starts, continue calling for more cooling to start third chiller.	Total primary flow = [] gpm]. Observe until secondary CHW flow => primary CHW flow = [] gpm] and both chillers are at least 95% loaded (by % of rated current), [] amps]. Time: []. After 20 minutes, 2nd lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 2nd lag chiller started = []. Observe that the amps on all running chillers are within 5% of each other.		
6 Seq 8; 32-34	Specs 15682 3.3.; 15683 3.2	<u>2nd Lag Secondary CHWP Staging ON Cont.</u> Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [] gpm, CHWP- [] rpm, CHWP- [] rpm] is greater than total design flow of ON SCHW pumps (1530 gpm), and the SCHW pump dP drops 2 psi [] below SPt [], for 10 minutes, the 2nd lag SCHWP turns ON. Observe that the 3 pumps' rpm are aprox. equal and at aprox. 67% (1170 rpm), [CHWP- [] rpm, CHWP- [] rpm, CHWP- [] rpm] and that total flow is just over previous gpm (1530) [] gpm], and that after ~ 2 minutes, pump dP is maintained at SPt [] and remote dP is maintained at SPt [].		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																								
7 Seq 8; 21-24	Specs 15682 3.3.; 15683 3.2	2nd Lag Cooling Tower Staging ON. During the preceding sequences:	<p>OSAT = [] F.</p> <p>Observe that when the 2nd lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when all three chillers are operating: [], [], [], [], [].</p> <p>Record of Observed Sequences:</p> <table border="1"> <thead> <tr> <th>Fan Spd</th> <th colspan="2">ECDWT</th> <th>Delay</th> </tr> <tr> <th></th> <th>ON (F)</th> <th>OFF (F)</th> <th>(min)</th> </tr> </thead> <tbody> <tr> <td>OFF</td> <td>[]</td> <td>--</td> <td></td> </tr> <tr> <td>(bypass valve modulating)</td> <td></td> <td></td> <td></td> </tr> <tr> <td>Low</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> <tr> <td>High</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> </tbody> </table>	Fan Spd	ECDWT		Delay		ON (F)	OFF (F)	(min)	OFF	[]	--		(bypass valve modulating)				Low	[]	[]	[]	High	[]	[]	[]		
Fan Spd	ECDWT		Delay																										
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Low	[]	[]	[]																										
High	[]	[]	[]																										

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
8 Seq 9, 10; 35	Specs 15682 3.3.; 15683 3.2	<p><u>Chillers Staging OFF.</u> Raise space setpoints so CCVs close, or shut off some or all AHU's. Wait ~10 minutes. Record time that primary flow exceeds secondary flow by capacity of last selected pump. Wait thru 20 min. delay. (CHWP 1-3 = 675 gpm ea., CHWP 4; 5 = 180gpm ea.)</p> <p>Repeat to see 1st lag chiller stage off.</p> <p>Repeat to see lead chiller stage off.</p>	<p><u>2nd Lag Chiller Staging OFF*</u> Observe that when the total SCHW gpm has reduced to be <= the sum of the first two selected SCHW pumps for 10 minutes, that the second lag SCHW pump shuts OFF.</p> <p>Primary CHW flow > secondary flow by _____ [] gpm. Time: []. After 20 minutes, 2nd lag chiller and pumps should stop. Time when 2nd lag chiller stops = []. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF.</p> <p><u>First Lag Chiller Staging OFF*</u> Observe that when the total SCHW gpm has reduced to be <= the lead SCHW pump for 10 minutes, that the first lag SCHW pump shuts OFF.</p> <p>Primary CHW flow > secondary flow by _____ gpm. Time: []. After 20 minutes, 1st lag chiller and pumps should stop. Time when 1st lag chiller stops = []. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF.</p> <p><u>Lead Chiller Staging OFF*</u> When all CCVs are < 15% open for 10 min. and after an additional 20 min. delay, lead chiller and all pumps should shut down.</p> <p>*No no-flow alarms should be generated during normal staging down.</p>		
9 Seq 41- 42	Specs 15682 3.3.; 15683 3.2	<p><u>CDP 6; 7 and HE-1.</u> Continuing with the last sequence of staging OFF the chillers: When the lead chiller shuts down CDP 6 or 7 still function.</p>	Observe that the CDP-6 or 7 and CDP 8 or 9 still run and that the CDWT remains the constant.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																				
10 Seq 41	Specs 15755 3.3	Heat Exchanger HE-1. With the chillers off, generate a significant load call from ACU's served by HE-1. Take temp. readings of entering and exiting HE water.	<p>Observe the temperature differences of the CDW and the ACU supply water across the heat exchanger. Verify that they are in line with the manufacturer's specs. Attach specs.</p> <p style="text-align: center;">Water Temps (F)</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;">CDW In</th> <th style="text-align: center;">CDW Out</th> <th style="text-align: center;">ACU In</th> <th style="text-align: center;">ACU Out</th> </tr> </thead> <tbody> <tr><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td></tr> <tr><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td></tr> <tr><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td></tr> <tr><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td><td style="text-align: center;">[]</td></tr> </tbody> </table>	CDW In	CDW Out	ACU In	ACU Out	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]	[]		
CDW In	CDW Out	ACU In	ACU Out																						
[]	[]	[]	[]																						
[]	[]	[]	[]																						
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[]	[]	[]	[]																						

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
11 Seq 33- 35	Specs 15682 3.3.; 15683 3.2	<p>Variable Speed Drive (VFD) on CHWP-6. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure 3 and 6.</p> <p>1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits.</p> <p>2. With only chiller associated with CHWP-6 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go.</p> <p>3. Call for moderate cooling or increase differential pressure setpoints.</p> <p>4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).</p>	<p>Motor manufacturer's recommended speed low limit = [] % of max.].</p> <p>1. Low limit setting in drive: [] Hz, rpm = [] % of maximum]. Provide reasons for low limit not being at motor mfr's low limit.</p> <p>List any anomalies noticed in programming:</p> <p>2. Lowest speed drive will go: [] Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is pump and remote dP SP maintained without hunting?</p> <p>3. Does VFD motor ramp up accordingly in a reasonable time? Is pump and remote dP SPt maintained without hunting?</p> <p>4. Does VFD motor ramp to full speed in a reasonable time? Is pump and remote dP SPt maintained without hunting?</p>		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
12 Seq 33- 35	Specs 15682 3.3; 15683 3.2	<p>Variable Speed Drive (VFD) on CHWP-7. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure 3 and 6.</p> <p>1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits.</p> <p>2. With only chiller associated with CHWP-7 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go.</p> <p>3. Call for moderate cooling or increase differential pressure setpoints.</p> <p>4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).</p>	<p>Motor manufacturer's recommended speed low limit = [] % of max.].</p> <p>1. Low limit setting in drive: [] Hz, rpm = [] % of maximum]. Provide reasons for low limit not being at motor mfr's low limit.</p> <p>List any anomalies noticed in programming:</p> <p>2. Lowest speed drive will go: [] Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is pump and remote dP SP maintained without hunting?</p> <p>3. Does VFD motor ramp up accordingly in a reasonable time? Is pump and remote dP SPt maintained without hunting?</p> <p>4. Does VFD motor ramp to full speed in a reasonable time? Is pump and remote dP SPt maintained without hunting?</p>		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
13 Seq 33- 35	Specs 15682 3.3.; 15683 3.2	<p>Variable Speed Drive (VFD) on CHWP-8. (Note: VFD operation with multiple SCHW pumps operating is tested in procedure T-3 and T-6.</p> <p>1. Carefully go over prefunctional checklist and programming record and identify anomalies. Record the low limits.</p> <p>2. With only chiller associated with CHWP-8 running and other chillers manually OFF, reduce all cooling load or manually lower pump and remote differential pressure setpoints. See how low VFD will go.</p> <p>3. Call for moderate cooling or increase differential pressure setpoints.</p> <p>4. Call for maximum cooling or increase differential pressure setpoints (keeping only 1 chiller ON).</p>	<p>Motor manufacturer's recommended speed low limit = [] % of max.].</p> <p>1. Low limit setting in drive: [] Hz, rpm = [] % of maximum]. Provide reasons for low limit not being at motor mfr's low limit.</p> <p>List any anomalies noticed in programming:</p> <p>2. Lowest speed drive will go: [] Hz, rpm]. Is this within 3 Hz of the low limit setting (or within a range equal to 5% of maximum speed)? Is SP maintained without hunting?</p> <p>3. Does VFD motor ramp up accordingly in a reasonable time? Is SP SPT maintained without hunting?</p> <p>4. Does VFD motor ramp to full speed in a reasonable time? Is SP SPT maintained without hunting?</p>		
14 Seq 8, 21-24; 32-35	Specs 15682 3.3.; 15683 3.2	<p>General Staging. By Monitoring: For each chiller, trend the status of CH, PCHWP, SCHWP, CDWP, CT pony fan, CT main fan, OSAT, CHWST, ECDWT, primary gpm, secondary gpm, VFD rpm for each pump. (Start all points simultaneously, 5 min. time step for 3 days, including weekend during a period of significant cooling. Provide text file (ASCII).</p>	<p>Observe that there are no anomalies in operation, comparing to the specified sequences and staging. This is not a detailed "to the minute" staging verification, which was done manually above.</p> <p>Attach representative graphs or columnar data and explanatory analysis to this test report.</p>		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
MISC. CHILLER SYSTEM FUNCTIONS					
15 Seq 13	Specs 15682 3.3.; 15683 3.2	<u>Demand Limiting.</u> With one chiller running, enable the demand limiting routine and temporarily reduce the limiting delay from 1 hour to 20 minutes. Lower the kW limit to be equal to 90% of the lead chiller design kW. Initiate sufficient load to call for two chillers.	Observe that CCV's run to 100% open, indicating a call for cooling and an unsatisfied condition. Note that the lag chiller is called for, but does not turn on until the programmed delay is over.		
16 Seq 1	Specs 15682 3.3.; 15683 3.2	<u>OSAT Lockout.</u> With chiller(s) running in auto, overwrite OSAT sensor to be 55F.	Observe a shutdown of the chillers, including secondary CHW pumps..		
17 Seq 1	Specs 15682 3.3.; 15683 3.2	<u>OSAT Lockout.</u> <u>By Monitoring.</u> During chilled water pressure control monitoring:	Observe a shutdown of the chillers, including secondary CHW pumps, whenever the OSAT is less than 55F Attach representative graphs or columnar data and explanatory analysis to this test report.		
18 Seq 19	Specs 15682 3.3.; 15683 3.2	<u>Primary CHW Pump Failure, CH-1; 2.</u> With only the lead chiller running (in auto), manually shut off the lead primary CHW pump	Operating chiller should stop and go into failure alarm. The lag chiller then becomes the lead chiller and should start.		
19 Seq 19	Specs 15682 3.3.; 15683 3.2	<u>Primary CHW Pump Failure, CH-3.</u> With the chiller running in auto, manually shut off the primary CHW pump.	An alarm should register and the standby primary CHW pump should start automatically.		
20 Seq 22	Specs 15682 3.3.; 15683 3.2	<u>CD Pump Failure, CH-1; 2.</u> With only the lead chiller running (in auto), manually shut off the CD pump.	Operating chiller should stop and go into failure alarm. The lag chiller then becomes the lead chiller and should start.		
21 Seq 22	Specs 15682 3.3.; 15683 3.2	<u>CD Pump Failure, CH-3.</u> With the chiller running in auto, manually shut off the primary CD pump.	An alarm should register and the standby CD pump should start automatically.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
22 Seq 37	Specs 15682 3.3.; 15683 3.2	<u>Secondary CHWP Failure.</u> With at least one chiller and pumps in auto, and running, shut off variable speed drive to lead SCHWP.	Observe that lag or standby SCHWP starts.		
23	Specs 15682 3.3.; 15683 3.2	<u>Chiller Standby 1.</u> With chillers manually OFF, turn 1st lag chiller to Auto and cause a call for the chillers.	Lead primary CHWP pump should start and orig. lead chiller should try and start, but fail. CHWP should shut off. After ____ [____] minutes DDC should start the lag CHW pump, etc. and 1st lag chiller and function as lead. (shorten delays for test, if desired)		
24	Specs 15682 3.3.; 15683 3.2	<u>Chiller Standby 2.</u> Repeat above to test 2nd lag chiller as lead.	First two chillers remain off. 2nd lag chiller starts.		
25 Seq 21	Specs 15682 3.3.; 15683 3.2	<u>Manual Standby CDP-</u> for CH-1 & 2. With chillers OFF, manually operate valves to allow standby CDP to function and assign as lead pump. Turn chillers to auto with CH-1 or 2 as lead. Initiate a call for the chillers.	Observe that standby CDP operates and that gpm is as per design, 1350 gpm [_____] gmp].		
26 Seq 18	Specs 15682 3.3.; 15683 3.2	<u>Manual Standby PCHWP-</u> for CH-1 & 2. With chillers OFF, manually operate valves to allow standby primary CHWP to function and assign it as lead pump. Turn chillers to auto with CH-1 or 2 as lead. Initiate a call for the chillers.	Observe that standby PCHWP operates as lead and that gpm is as per design, 675 gpm [_____] gpm].		
27 Seq 43	Specs 15682 3.3.; 15683 3.2	<u>CDP 6; 7 Failure</u> Lead = CDP-____ (6 or 7) With system in auto and running, manually shut down lead pump. <u>CDP 8; 9 Failure</u> Lead = CDP-____ (8 or 9) With system in auto and running, manually shut down lead pump.	Observe that an alarm is registered and that the lag pump starts. Observe that an alarm is registered and that the lag pump starts.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
28 Seq 6;7	Specs 15682 3.3.; 15683 3.2	<p>CHWS Reset.</p> <p>With one or more chillers running in auto, change conditions to provide data points near both ends of the line and one near the middle of the chart below.</p> <p>A. Mark current SPt conditions on chart with a star and CHWSTemp with a dot.</p> <p>B. Increase cooling demand by lowering space setpoints 8°F in all zones or by manually opening preheat coil valves. In BAS, observe CCV's opening for AHU 1, 2, 3; 4 and CHWS setpoint lowering. Mark SPt values on chart with a star. Observe that the CHWST meets setpoint w/o excessive hunting. Mark CHWST values on chart with a dot.</p> <p>C. Remove cooling demand by raising space setpoints 8°F above normal in all zones or by other suitable method. Observe CCV's closing for AHU 1, 2, 3; 4 and CHWS setpoint raising. Mark SPt values on chart with a star. Observe that the CHWST meets setpoint w/o excessive hunting. Mark CHWT values on chart with a dot.</p> <p>D. In condition B, Overwrite RA RH to be 53%.</p>	<p>A. Values in middle of chart; near line.</p> <p>B. Values in the bottom right of chart; near the line.</p> <p>C. Values in the top left of chart; near the line.</p> <p>D. Observe that the SPt does not change further.</p>		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
<p>CHWST Reset Chart.</p> <p>For each observation, mark CHWS temp with a dot and the current CHWS temperature setpoint with a star. After system settles, all values should fall within 1F of the line and the actual temp. should be within 1F of setpoint.</p> <p>Note how many minutes after the call for a change was made, that readings were recorded.</p> <div> <p>CHWST Set Point and Temp</p> <p>Number of CCV's >= 90% Open</p> </div>					
29 Seq 6	Specs 15682 3.3.; 15683 3.2	CHWS Temperature Reset. By Monitoring: Trend CHWST setpoint, CHWS temperature, CCV positions for AHU 1, 2, 3; 4. (Start all points simultaneously, 5 min. time step for 5 days, including weekend. Provide text file (ASCII)).	Make similar observations as for the manual test. Observe that the CHWS SPt changes as expected and CHWST meets setpoint w/o excessive hunting. Attach representative graphs or columnar data and explanatory analysis to this test report.		

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30 Seq 33	Specs 15682 3.3.; 15683 3.2	<p><u>Chilled Water Pressure Control.</u> Setpoint is to have one CCV 80% open. With one or more chillers running in auto and with all CCV's less than 80% open. Increase the call for cooling by lowering DAT or space temperature setpoint.</p> <p>Increase the call for cooling by lowering DAT or space temperature setpoint.</p> <p>Significantly increase the call for cooling by lowering DAT or space temperature setpoint.</p>	<p>Beginning pump dP SPt: [] Beginning remote dP SPt:[] Observe that that when the first CCV opens more than 80% []% the remote dP SPt increases relative to how much greater than 80% open the CCV is. New remote dP SPt = [] and new dP = []. Observe that the pump dP SPt also increases. New pump dP SPt = [] and new dP = []. Observe that the SCHW pump speed increases to meet the pump dP SPt.</p> <p>Observe that after a forced 5 min. delay, if the most open CCV is less than 80% open [], the remote and pump dP SPt's decrease and SCHW pump speed decreases.</p> <p>Observe that as the load is increased substantially, that dP SPt's increase to try and maintain only one CCV greater than 80% open. More than one CCV may be open more than 80% at the same time, but not for more than 5-10 minutes.</p>		
31 Seq 33	Specs 15682 3.3.; 15683 3.2	<p><u>Chilled Water Pressure Control.</u> <u>By Monitoring.</u> Trend all CCV positions, pump discharge differential pressure and setpoint, remote pressure and setpoint, VFD rpm on each CHW pump; OSAT.</p> <p>Trend during season of moderate to significant cooling for 3 days at a sampling rate of every 5 minutes; 24hrs per day with output in ASCII file columnar format.</p>	<p>Observe that there is generally only one CCV more than 80% open. At times, not lasting more than about 10 minutes, there could be more than one CCV more than 80% open. The goal is to have one, and only one, CCV 80% open at all times.</p> <p>Attach representative graphs or columnar data and explanatory analysis to this test report.</p>		
32 Seq 5	Specs 15682 3.3.; 15683 3.2	<u>System Stabilization.</u> Analyze CHW reset and pressure control monitoring data.	Verify that the CHWS temperature is stable and maintains the CHWS SPt within 0.5F over a range of conditions and days.		

Notes:

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33 Seq 40	Specs 15682 3.3.; 15683 3.2	<u>Secondary Pumps for Freeze Protection.</u> With chillers in auto, but not running, manually start smoke exhaust system EF-10 and overwrite OSAT to be 38F.	Observe that SCHW pumps operate normally. (EF-10-associated AHU CCV's should also be open).		
34 Seq 5	Specs 15683 3.2	<u>CH-3 (Reciprocating) Staging.</u> <u>By Monitoring.</u> Temporarily program the BAS to readout and trend the stage of CH-3. With CH-3 as lead chiller in auto, call for chillers using a suitable method. After CH-3 is fully loaded, remove all load. During the above, trend the CH-3 stage, the CHWST and the CHWST Spt at 2 min. Intervals for 1 hour or until chiller is fully loaded and then unloads to stop. Provide tabular or graphical documentation.	<u>Loading:</u> The trends should follow the 8 staging sequences of stage vs CHWST offset from setpoint (accounting for programmed delays), etc. as per the programmed sequences. <u>Unloading:</u> The trends should follow the staging sequences of stage vs CHWST offset from setpoint (accounting for programmed delays), etc. as per the programmed sequences. Attach representative graphs or columnar data and explanatory analysis to this test report.		
35	--	For all chiller and cooling tower components, review current setpoints and sequences with specifications and control drawings. Submit approved differences to be incorporated in asbuilts.	Setpoints and sequences are the same as original specs. OR Differences submitted for asbuilts.		
CHILLER SAFETY CONTROLS					
36 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	<u>CHW Flow Switch CH-1.</u> If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 1 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		
37 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	<u>CHW Flow Switch CH-2.</u> If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 2 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		

Notes:

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38 Seq 2; 3	Specs 15682 3.3.; 15683 3.2	<u>CHW Flow Switch CH-3.</u> If PCHW pump is wired in series with proof of flow switch, jumper pump out of this loop. With chillers manually off, but under conditions that will call for chillers, manually turn off PCHW pump. Turn Chiller 3 to auto.	Observe that chiller won't start because of no CHW flow and that an alarm is generated.		
39 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>Low evap. refrigerant temp/pressure</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
40 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>High condenser pressure</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
41 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>High motor winding temperature</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
42 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>Low differential oil pressure</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
43 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>Low differential oil pressure</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		

Notes:

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44 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>Loss of any electrical power phase</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
45 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>High oil temperataure</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
46 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>High bearing temperature</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
47 McQuay O&M	Specs 15682 3.3.; 15683 3.2	<u>Ground fault protection</u> TBD CH-1 CH-2 CH-3	Indicator lights for alarms, cutouts and normal running function properly. Compressor does not restart after cutout.		
48	Specs 15682 3.3.; 15683 3.2	<u>Interlocking of chillers and pumps</u> This is demonstrated in procedures above (not the safeties).			
OTHER COOLING TOWER FUNCTIONS					
49 Seq 28	Specs 15682 3.3.; 15710 2.2	<u>CT-1 Fan Failure Alarm.</u> With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		
50 Seq 28	Specs 15682 3.3.; 15710 2.2	<u>CT-2 Fan Failure Alarm.</u> With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		

Notes:

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51 Seq 28	Specs 15682 3.3.; 15710 2.2	<u>CT-3 Fan Failure Alarm.</u> With CT running, manually shut off either of its fan motors.	Observe that an alarm is registered. Lag CT comes on line automatically??? Manually???		
52 Seq 29	Specs 15682 3.3.; 15710 2.2	<u>CT Vibration Alarm.</u> (if not documented during startup) Jump the vibration sensor to simulate a vibration alarm. <u>CT-1:</u> <u>CT-2:</u> <u>CT-3:</u>	Observe that an alarm is registered and that the CT fan shuts off. Lag CT comes on line automatically??? Manually???		
53 Seq 25	Specs 15682 3.3.; 15710 2.2	<u>CT High Water Alarm.</u> Plug sump overflow and override the makeup valve, causing the CT sump to over-fill.	Observe that a high water limit alarm is registered.		
54 Seq 27	Specs 15682 3.3.; 15710 2.2	<u>CT Low Water Alarm and Makeup</u> Override the makeup valve, causing the CT sump to not-fill. Drain the sump below the alarm level. Return makeup valve to auto.	Observe that a low water limit alarm is registered. Observe makeup valve open slowly and fill sump until proper level; then close.		
55 Seq 30	Specs 15682 3.3.; 15710 2.2	<u>Winter Operation.</u> During weather with OSAT below 25F, inspect CT.	Observe the functioning of the heat tape, verify that the sump temperature is above setpoint, verify that freezing water on the media is not excessive. Be sure that the fans do not come on when water is going over the tower (as only 60F need be achieved).		

Notes:

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56 Seq 26	Specs 15682 3.3; 15710 2.2	CT Sump Heaters. (if not documented during startup) Schedule: (setpoint = 45F) <div style="display: flex; justify-content: space-around;"> ON (F) OFF (F) </div> Stage 1 45 43 Stage 2 47 45 Starting with sump heaters not running, overwrite sump temperature to be equal to stage 1 SPt. Then, lower to stage 2 SPt. Then raise to 1 F above 2nd stage OFF SPt. Then lower to 1st stage OFF SPt. Repeat for each CT.	Actual: <div style="display: flex; justify-content: space-around;"> ON (F) OFF (F) </div> CT-1 Stage 1 <input type="text"/> <input type="text"/> Stage 2 <input type="text"/> <input type="text"/> CT-2 Stage 1 <input type="text"/> <input type="text"/> Stage 2 <input type="text"/> <input type="text"/> CT-3 Stage 1 <input type="text"/> <input type="text"/> Stage 2 <input type="text"/> <input type="text"/>		

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REPEAT PROCEDURES 1-8 WITH CHILLER 2 AS LEAD:																																								
CHILLER SYSTEM STARTUP AND STAGING (2nd chiller as lead)																																								
1b Seq 1-4, 16, 20-23; 32		<p><u>Startup Sequence.</u> Lead = CH-____. (This is not the <u>initial</u> startup by factory reps). With chiller system off, with schedule allowing chillers ON and OSAT >56F, turn chillers and pumps to auto. Turn on AHUs and cause a call for cooling sufficient to call for chillers (manually open preheat coil valve, lower space temperature SPt, etc. A call for the chillers will be made when any AHU fan is ON and its CCV is => 15% open for 10 minutes.</p> <p style="text-align: center;"><u>Vanes:</u></p> <p style="text-align: center;"><u>Cooling Tower:</u> Specified Sequences:</p> <table border="1"> <thead> <tr> <th></th> <th colspan="2">ECDWT</th> </tr> <tr> <th>Fan Spd</th> <th>ON (F)</th> <th>OFF (F)</th> </tr> </thead> <tbody> <tr> <td>OFF (bypass valve modulating)</td> <td><69</td> <td>---</td> </tr> <tr> <td>*Low</td> <td>69</td> <td>75</td> </tr> <tr> <td>*High</td> <td>73</td> <td>69</td> </tr> </tbody> </table> <p>* Bypass valve should be closed. Eight minute delay between stages.</p> <p>Maintain chiller load between 10-15% for 30 minutes.</p>		ECDWT		Fan Spd	ON (F)	OFF (F)	OFF (bypass valve modulating)	<69	---	*Low	69	75	*High	73	69	<p>Observe that the lead primary CHW pump does not turn ON until a CCV on an ON AHU is => 15% [] open for 10 min. [].</p> <p>Observe lead secondary CHW pump start when a CCV is 15% [] open for 10 [] minutes.</p> <p>Observe CHW primary and secondary pumps turning on, then the oil pump; then the CD pump (30-60s delay ea.)</p> <p>Observe that secondary pumps start at minimum RPM and slowly ramp up. Starting RPM = [].</p> <p>Observe the lead chiller starting. Observe that the vanes start closed and begin to open. (max spd = 0-full open in ~3 min. and closed in ~1 minute)</p> <p>OSAT = [] F.</p> <p>Observe that when the lead chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps during lead chiller operation only: [], [], [], [], [].</p> <p>Record of Observed Sequences:</p> <table border="1"> <thead> <tr> <th></th> <th colspan="2">ECDWT</th> <th>Delay (min)</th> </tr> <tr> <th>Fan Spd</th> <th>ON (F)</th> <th>OFF (F)</th> <th></th> </tr> </thead> <tbody> <tr> <td>OFF (bypass valve modulating)</td> <td>[]</td> <td>---</td> <td></td> </tr> <tr> <td>Low</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> <tr> <td>High</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> </tbody> </table> <p>Observe that there is no surging or abnormal vibration.</p>		ECDWT		Delay (min)	Fan Spd	ON (F)	OFF (F)		OFF (bypass valve modulating)	[]	---		Low	[]	[]	[]	High	[]	[]	[]		
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2b Seq 8		<u>1st Lag Chiller Staging ON.</u> Staging sequence: CH-___ -->CH-___ -->CH-___ With chillers in auto, and loaded such that only lead chiller is running, lower space setpoints so CCVs open. Wait ~10 minutes. Record time that primary flow and secondary flow become equal. Wait 20 minutes.	Total primary flow = [_____] gpm]. Secondary CHW flow => primary CHW flow = [_____] gpm] and lead chiller is at least 95% loaded (by % of rated current), [_____] amps]. Time: [_____] . After 20 minutes, 1st lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 1st lag chiller started = [_____] . Observe that the amps on both chillers are within 5% of each other.																																
3b Seq 8; 32-34		<u>1st Lag Secondary CHWP Staging ON.</u> Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [_____] gpm, [_____] rpm] > total design flow of ON SCHW pumps (765 gpm), and the SCHW pump dP drops 2 psi [_____] below SPT for 10 minutes, the first lag SCHWP turns ON. Observe that the 2 pumps' rpm are approx. equal and at approx. 50% (880 rpm), [CHWP-_____] rpm, CHWP-_____] rpm] and that total flow is just over previous gpm (765) [_____] gpm], and that after ~ 2 minutes, pump dP is maintained at SPT [_____] [_____] and remote dP is maintained at SPT [_____] [_____] .																																
4b Seq 8; 21-24		<u>1st Lag Cooling Tower Staging ON.</u> During the preceding sequences:	OSAT = [_____] F]. Observe that when the 1st lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT SPT of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when both chillers are operating: [_____] , [_____] , [_____] , [_____] , [_____] . Record of Observed Sequences: <table border="1"> <thead> <tr> <th></th><th>Fan Spd</th><th>ON (F)</th><th>ECDWT</th><th>OFF (F)</th><th>Delay (min)</th></tr> </thead> <tbody> <tr> <td>OFF</td><td>[_____] </td><td>[_____] </td><td>---</td><td>[_____] </td><td>[_____] </td></tr> <tr> <td>(bypass valve modulating)</td><td></td><td></td><td></td><td></td><td></td></tr> <tr> <td>Low</td><td>[_____] </td><td>[_____] </td><td>[_____] </td><td>[_____] </td><td>[_____] </td></tr> <tr> <td>High</td><td>[_____] </td><td>[_____] </td><td>[_____] </td><td>[_____] </td><td>[_____] </td></tr> </tbody> </table>		Fan Spd	ON (F)	ECDWT	OFF (F)	Delay (min)	OFF	[_____]	[_____]	---	[_____]	[_____]	(bypass valve modulating)						Low	[_____]	[_____]	[_____]	[_____]	[_____]	High	[_____]	[_____]	[_____]	[_____]	[_____]		
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High	[_____]	[_____]	[_____]	[_____]	[_____]																														

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
5b Seq 8		<u>2nd Lag Chiller Staging ON Cont.</u> After second chiller starts, continue calling for more cooling to start third chiller.	Total primary flow = [] gpm. Observe until secondary CHW flow => primary CHW flow = [] gpm] and both chillers are at least 95% loaded (by % of rated current), [] amps]. Time: []. After 20 minutes, 2nd lag chiller should start (PCHWP - oil pump - CDP - chiller). Time when 2nd lag chiller started = []. Observe that the amps on all running chillers are within 5% of each other.		
6b Seq 8; 32-34		<u>2nd Lag Secondary CHWP Staging ON Cont.</u> Continue increasing cooling load, if necessary, to cause CCVs to open further.	Observe that after total SCHW flow [] gpm, CHWP- [] rpm, CHWP- [] rpm] is greater than total design flow of ON SCHW pumps (1530 gpm), and the SCHW pump dP drops 2 psi [] below SPt [] for 10 minutes, the 2nd lag SCHWP turns ON. Observe that the 3 pumps' rpm are aprox. equal and at aprox. 67% (1170 rpm), [CHWP- [] rpm, CHWP- [] rpm, CHWP- [] rpm] and that total flow is just over previous gpm (1530) [] gpm], and that after ~ 2 minutes, pump dP is maintained at SPt [] and remote dP is maintained at SPt [].		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																								
7b Seq 8; 21-24		2nd Lag Cooling Tower Staging ON. During the preceding sequences:	<p>OSAT = [] F.</p> <p>Observe that when the 2nd lag chiller started the CT specified sequences followed, with delays between stages. Observe that the ECDWT Spt of 65F is maintained, unless OSA conditions prohibit. Record various ECDW temps when all three chillers are operating: [], [], [], [], [].</p> <p>Record of Observed Sequences:</p> <table border="1"> <thead> <tr> <th>Fan Spd</th> <th colspan="2">ECDWT</th> <th>Delay</th> </tr> <tr> <th></th> <th>ON (F)</th> <th>OFF (F)</th> <th>(min)</th> </tr> </thead> <tbody> <tr> <td>OFF</td> <td>[]</td> <td>---</td> <td></td> </tr> <tr> <td colspan="4">(bypass valve modulating)</td> </tr> <tr> <td>Low</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> <tr> <td>High</td> <td>[]</td> <td>[]</td> <td>[]</td> </tr> </tbody> </table>	Fan Spd	ECDWT		Delay		ON (F)	OFF (F)	(min)	OFF	[]	---		(bypass valve modulating)				Low	[]	[]	[]	High	[]	[]	[]		
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High	[]	[]	[]																										

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
8b Seq 9; 10; 35		<p><u>Chillers Staging OFF.</u> Raise space setpoints so CCVs close, or shut off some or all AHU's. Wait ~10 minutes. Record time that primary flow exceeds secondary flow by capacity of last selected pump. Wait thru 20 min. delay. (CHWP 1-3 = 675 gpm ea., CHWP 4; 5 = 180gpm ea.)</p> <p>Repeat to see 1st lag chiller stage off.</p> <p>Repeat to see lead chiller stage off.</p>	<p><u>2nd Lag Chiller Staging OFF*</u> Observe that when the total SCHW gpm has reduced to be <= the sum of the first two selected SCHW pumps for 10 minutes, that the second lag SCHW pump shuts OFF.</p> <p>Primary CHW flow > secondary flow by _____ [] gpm. Time: []. After 20 minutes, 2nd lag chiller and pumps should stop. Time when 2nd lag chiller stops = []. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF.</p> <p><u>First Lag Chiller Staging OFF*</u> Observe that when the total SCHW gpm has reduced to be <= the lead SCHW pump for 10 minutes, that the first lag SCHW pump shuts OFF.</p> <p>Primary CHW flow > secondary flow by _____ gpm. Time: []. After 20 minutes, 1st lag chiller and pumps should stop. Time when 1st lag chiller stops = []. Cooling tower fans shut down as expected: Main fan--pony motor--all OFF.</p> <p><u>Lead Chiller Staging OFF*</u> When all CCVs are < 15% open for 10 min. and after an additional 20 min. delay, lead chiller and all pumps should shut down.</p> <p>*No no-flow alarms should be generated during normal staging down.</p>		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
57	15682 3.3.C; D	<p>Chiller Efficiency Testing and Benchmarking.</p> <p>The efficiency and capacity testing specified shall be substituted with the following efficiency benchmarking. In summary this will consist of:</p> <p>A. Obtain calculated kw/ton values from the mf'r for each chiller model for all possible combinations of 4 ECDW temps, 4 LCHW temps and 100, 75, 50 and 25% loads, totalling 60 points. Plot kw/ton vs % Load. Perform a regression based on DOE-2 chiller curve equation forms through the data, using the PG&E Chiller Performance Evaluation Tool. Use the same equation form for each chiller model.</p> <p>B. During a near design day and a moderate cooling day, trend the LCHWT, ECDWT, kw, RCHWT, CHW gpm at 15 min. intervals over the occupied period. Calculate % load and tons at each point. Trend each chiller as needed to establish a good variety of load, ECDWT and reset CHWT. Plot kw/ton vs % Load. Perform a regression based on the same curve forms as for the mf't data.</p> <p>C. Compare the chiller plots in B. to mf'r's plots in A. Significant difference between mf'r data in A and actual data plots in B may indicate problems. If the ARI APLV (Application Part Load Value) kw/ton efficiency calculated in the PG&E tool, for the actual chiller is more than 15% greater than the calculated APLV from the mf'r data, then full site verification and testing of full and part load efficiencies at ARI conditions, as per the original specs, will be necessary, unless the reason for inefficiency can be traced to site installation problems and remedied.</p> <p>D. Compare the chiller plots in B for the identical chillers. Significant differences between CH-1 and CH-2 actual plots in B may indicate problems with one of the chillers.</p> <p>E. The plots in B provide the efficiency benchmark for these chillers. Similar tests can be completed annually to verify and ensure continued efficient chiller operation by comparing curve fit regressions of current operation with that of the original benchmarks.</p> <p>The commissioning consultant (PECI) shall perform all data analysis for the benchmarking and submit a full report of the process and results.</p>			
58	—	Return all changed control parameters and conditions to their pre-test values⁵	Check off in table of Section 2 above when completed		

SEQUENCES AND COMPONENTS NOT TESTED

59		<u>Vibration Isolators.</u> Not tested.			
60		<u>Capacity Testing</u> Not tested.			

Notes:

61		<u>SCHW Pump End of Curve Safety.</u> Not tested (from examining the pump curves and operating points, pumps are sufficiently oversized to make an end of curve event highly unlikely)		
MONITORING AND TREND LOGGING Monitoring via BAS trend logs are required per test procedures 14, 17, 29, 31, 34; 57. Attach representative graphs or columnar data and explanatory analysis to this test report.				

****Abbreviations:** SCHW = secondary chilled water, PCHW = primary chilled water. dP = diff. pressure, SPt = setpoint
CHWS = chilled water supply, CT = cooling tower, BAS = building automation system.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

⁶Methods to False Load Chillers

- 1) If OSAT is less than 75F, prevent economizer cool OSA from entering the building.
 - a) Manually close the economizer OSA dampers, OR
 - b) Lower the changeover economizer setpoint below the OSAT (if DB type), OR lastly
 - c) Overwrite the OSAT value to be 80F or more so dampers won't open.
- 2) Use OSA preheat coils to heat incoming OSA.
Enable the boiler by removing any lockouts, etc. Manually open the min. OSA preheat coil valve to preheat the OSA. Increase the min. OSA discharge temperature setpoint and the heating water supply temperature, as necessary.
- 3) Lower the space temperature setpoint.
- 4) Prior to the chiller test, manually preheat the building space temperature to 78F - 80F.
- 5) Lower the chilled water supply temperature setpoint.

False Loading Cooling Towers

- 1) False load the chiller (see above)

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

– END OF TEST –

Notes:

Functional Test

Project: _____

FT-____ HEATING FAN COIL FCU-1, Room B-102

Related Tests: Boilers

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____

Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing: __ FCU-1
 - b. __ Boilers 1; 2 have successfully completed functional testing.
 - c. __ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.
- _____
Controls Contractor Signature or Verbal Date
- d. __ All A/E punchlist items for this equipment corrected.
 - e. __ Safeties and operating ranges reviewed.
 - f. __ Test requirements and sequences of operation attached.
 - g. __ Schedules and setpoints attached.
 - h. __ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
 - i. __ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 - j. __ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 - k. __ **Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:**

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
FCU-1 setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓

Notes:

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
FCU-1 stat temp.		Stat:		Stat:	

¹Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

---NONE---

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____
 ___ Unit mounted securely. ___ Unit accessible for servicing. ___ No unusual noise or vibration in fan.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		Adjust the stat setpoint until it is equal to the space temp.	___ Fan starts. ___ Heating coil valve opens; ___ warm air delivered.	
2 Seq. 1		Adjust the stat setpoint until it is 4F below the space temp.	Fan stops. Heating coil valve closes.	
3	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Test

Project: _____

FT-_____ FIN TUBE RADIATOR FT _____

(There are _____ fin tubes in this project and _____ will be tested.)

Related Tests: Boilers, Interlocked TU-_____

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing: TU's _____.
 - b. ___ Boilers have successfully completed functional testing.
 - c. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.
- _____
- Controls Contractor Signature or Verbal Date
- d. ___ All A/E punchlist items for this equipment corrected.
 - e. ___ Safeties and operating ranges reviewed.
 - f. ___ Test requirements and sequences of operation attached.
 - g. ___ Schedules and setpoints attached.
 - h. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
 - i. ___ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 - j. ___ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.
—NONE—

Notes:

4. Device Calibration Checks. Check the actuators or devices listed below for calibration.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Heating coil valve (HCV): Set pumps to normal mode. *Procedure 1.* Command valve to a few intermediate positions. Verify that reading in BAS reasonably correspond to the actual positions. For heating coil valves (NO): Procedure 2a. Set heating setpoint 20°F above room temperature. Verify BAS reading says 100% open. Visually verify valve is fully open. *2b.* Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change. *Procedure 3.* Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. *4.* For pneumatic actuators, by override in the EMS, increase pressure to valve by 3psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal.

Device or Actuator & Location	Procedure / State	BAS Value	Site Observation	Corrections	Pass Y/N
Heating coil valve (HCV) position or command and stroke	1. Intermediate positions				
	2a. Full open				
	2b. Remove power or air (full open)				
	3. Closed				
	4. Increase pressure (close)				

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____
 ___ Unit mounted securely. ___ Valves and unit accessible for servicing.

Notes:

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1		<u>General Sequencing.</u> a. With boilers in normal mode and ON, increase space setpoint 20F of TU-_____ (interlocked to the fin tube). If OSAT is not > 40F, overwrite it to be > 40F. Overwrite space temp to be 3F below main setpoint (cooling) _____ F and observe in BAS that there is heating deck flow and cooling flow goes to minimum. Observe that the fin tube or radiant panels remain OFF. b. Change the space temp. to be 5F below main setpoint (cooling) _____ F and observe the radiant panels or fin tubes remain OFF. c. Change the OSAT to be < 40F. Observe that the radiant panels or fin tubes start heating. Return all parameters to normal.	a. TU goes into heating mode. Fin tube HCV's remain closed. b. TU remains in heating mode. Fin tube HCV's remain closed. c. TU remains in heating mode. Fin tube HCV's open.	
2		Lower space setpoint to 20F below space temperature of TU-_____.	TU goes into cooling mode. Fin tube heating valve closes equally with TU heating command (TU HCV or dual duct heating damper).	
3		<u>Valve Leakage Test.</u> After 1 hour or more with fin tube heating valve closed, verify that no hot water is leaking through valve by feeling fin tube 3 feet from valve.	Tube should be near room temperature.	
4		<u>Trend Logs.</u> NONE		
5				
6	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes¹Sequences of operation specified in Contract Documents (attached).²Mode or function ID being tested, per testing requirements section of the project Specifications.³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.⁴Include tolerances for a passing condition.⁵Record any permanently changed parameter values and submit to Owner.**— END OF TEST —**Notes:

Functional Test

Project: _____

**FT-04_____ PACKAGED ROOFTOP DX AIR CONDITIONING UNIT
RTU _____**

**Including integral equipment: ___supply fans, ___relief fan,
___inlet vanes, ___variable speed drive**

Related Tests: _____

1. Participants

<u>Party</u>	<u>Participation</u>
_____	_____
_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:

___ Duct system

___ Connected Terminal Units

___ _____

- b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal

Date

- c. ___ Vibration control report approved (if required).
d. ___ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
e. ___ All A/E punchlist items for this equipment corrected.
f. ___ These functional test procedures reviewed and approved by installing contractor.
g. ___ Safeties and operating ranges reviewed.
h. ___ Test requirements and sequences of operation attached.
i. ___ Schedules and setpoints attached.

Notes:

- j. ☐ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, override on OSA dampers, etc.)
- k. ☐ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
- l. ☐ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- m. ☐ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- n. ☐ **Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:**

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒
Supply air temp.		
Discharge static pressure (SP)		
Supply air reset schedule		
Bldg. static P.		
Low ambient lockout		
NLL return air setpt.		

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒
High duct SP alarm		
Econ. min. when VFD or IGTV @ 0%	%	%
Econ. min. when VFD or IGTV @ 100%	%	%
Space temp. setpoint		
NLL space temp. setpt.		

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Notes:

Sensor & Location	Location OK ¹	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
SAT		Pkg: BAS:		Pkg: BAS:	
RAT		Pkg: BAS:		Pkg: BAS:	
OSAT		Pkg: BAS:		Pkg: BAS:	
Disch. SP		Pkg: BAS:		Pkg: BAS:	
Enthalpy		Pkg:		Pkg:	

¹Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	Procedure / State	1st Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
Inlet guide vane position*	1. Closed				
	2. Full open				
Variable frequency drive speed* (VFD)	1. Min.: %				
	2. Max.: %				
OSA damper position**	1. Closed				
	2. Full open				

***Vanes or VFD:** *Procedure 1.* Lower the controlling static pressure setpoint (duct or discharge) to be 1/4 of its current value. Verify that the vanes are shut, or fan speed is at minimum for VFD and packaged controller reads the same. Return the static pressure setpoint to normal. *Procedure 2.* Lower the space temperature setpoint to be 20F below space temp. and cause TU dampers to go to full cooling. Raise the static pressure setpoint as necessary to cause the setpoint to not be met. Verify that the inlet vanes are fully open or the fan speed is at its max. and verify that the packaged controller reads the same. Return all to normal.

****OSA Damper:** *Procedure 1.* Change minimum OSA damper position setting to 0%. Change economizing parameter as necessary to cause damper to go to minimum. Verify that the damper is shut. Change the minimum OSA damper position setting to 100%. Verify that the damper is fully open. Return all to normal.

Notes:

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N

General Conditions of Test

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1; 31-33		Observe the unit in OFF condition.	Inlet vanes closed, [], relief and OSA dampers closed, RA dampers open []. Associated exhaust fan(s) are OFF.	
2 Seq. 2; 3; 31- 33		Disable optimum start. With the ASU in auto and with the schedule in unoccupied, change schedule to be occupied in a few minutes. Change the warm-up mode setpoint to be 3F greater than the RA temperature.	Upon the occupied time the unit should start. Observe that the inlet vanes are closed [] when the unit starts. Associated exhaust fan(s) are ON.	
3 Seq. 5; 22; 34		<u>Warm-up Mode.</u> Continuing with the last procedure observe the startup.	1) Economizer dampers are shut. 2) Perimeter TU box reheat valves open (observe 1/2 of designated perimeter TU's thru BAS). 3) Associated exhaust fan(s) are OFF.	
4 Seq. 6		Wait until the RA temperature rises sufficiently, or change the warmup mode setpoint to be = to RA temperature + any offset.	Perimeter reheat valves return to normal. Economizer damper returns to normal (minimum position). (Note: min. position varies with fan inlet vane position.)	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
5 Seq. 7		<p><u>Volume Capacity Control.</u> Return all settings to normal. Record discharge static pressure.</p> <p>Command all TU dampers to minimum (via direct command or by raising the space temp. setpoint 20F above space temp).</p> <p>Command all TU dampers to max. cooling (via direct command or by lowering the space temperature setpoint 20F below space temp.).</p>	<p>1) Discharge static pressure setpoint = [].</p> <p>Current static pressure = [].</p> <p>2) Inlet vanes should go to their minimum position (0% open) []% in [] minutes].</p> <p>3) Static pressure should remain at setpoint [].</p> <p>4) Inlet vanes should go to their max. position (100% open) []% in [] minutes].</p> <p>4) Static pressure should remain at setpoint [].</p>	
6 Seq. 7		<p><u>TREND LOG 1 Volume Capacity Control.</u> Since the discharge pressure is not monitored, trend the inlet vane position command and OSAT for 8 hours in 1 minute intervals, with all systems in normal mode. Include transition from unoccupied to occupied periods. Attach occupied schedule. See Monitoring section at the end of this test.</p>	<p>Verify that the inlet vanes are not hunting excessively in trying to maintain the static pressure setpoint. If there is not a wide enough range of vane positions logged, repeat the trend with some simulated load conditions being applied.</p>	
7 Seq. 8		<p>Lower the ASU high static setpoint to be 0.1 inch lower than the current discharge static pressure. When done, return setpoint to normal.</p>	<p>ASU should shut down []..</p>	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
8 Seq. 12; 18; 20		<p><u>Cooling Capacity Staging.</u></p> <p>a) Shut the ASU OFF. Raise the space temperature setpoints 10F above space temperatures. If the OSAT is >55F, overwrite the OSAT sensor, that controls the economizer, to be 55F. Turn ASU ON.</p> <p>b) Change SAT reset parameters so that at full economy, the SAT setpoint will still not be met upon a call for full cooling (so SAT setpoint will be >OSAT). Record changes</p> <p>_____.</p> <p>_____.</p> <p>c) Lower the space temperature setpoints to 20F below space temperatures.</p>	<p>a) SAT setpoint should change upward according to the strategy parameters [_____]. Compressors should be OFF [_____]. Economizer damper should be at minimum [_____]. (Note: min. position varies with fan inlet vane position.)</p> <p>b) SAT setpoint should change downward according to the strategy parameters [_____]. Compressors should be OFF [_____]. Economizer dampers should open over time go to full open [_____]. SAT setpoint will not be met.</p> <p>c) Compressors begin to stage ON, only after economizer dampers are fully open [_____]. Economizer damper remains fully open [_____].</p>	
8 cont. Seq. 12		<p>Continuing from above:</p> <p>If temperatures are so low that the OSA with only the lower stages of mechanical will meet the SAT setpoint, lower the enthalpy changeover setpoint to 10 Btu/lb, so economizer damper will go to minimum.</p>	<p>Observe the staging ON of multiple compressors and their condenser fans.</p> <p>[_____].</p> <p>Observe that SAT setpoint is met at all times, within 1F either side of the current deadband (+/- 4F). Maximum deviation observed [_____].</p> <p>If OSAT is too cold for full compressor staging, repeat this sequence in warmer weather.</p>	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #												
9 Seq. 14		<u>Compressor Lockout.</u> Continuing from above, change the compressor lockout temperature to be 3F below the current OSAT. Change the compressor lockout temperature to be 1F above the current OSAT. Return all settings to normal.	Compressors should remain ON. Compressors should shut OFF.													
10 Seq. 12; 16- 20		<u>TREND LOG 2. Cooling Capacity Staging and Economizer.</u> With all systems in normal mode, trend the OSAT, RAT, SAT, SAT setpoint, ASU inlet vane position command and datalog the compressor current. Synchronize datalogger and BAS time and starts. Sample at 5 min. intervals for 48 hours during weather near design cooling. Provide occupied schedule. See Monitoring section at the end of this test.	Observe that SAT setpoint is met at all times, within 1F either side of the current deadband (+/- 4F). Observe that economizer is first stage of cooling and that compressors stage ON and OFF according to need to maintain SAT setpoint. Verify that the compressors comply with the min. ON and OFF time of 3 minutes.													
11 Seq. 15		<u>SAT Reset.</u> a) With all systems in auto, make sure all polled zones are within 4F of space setpoint. Record the zone farthest above its setpoint. b) Overwrite a zone space temp to be 5F above its setpoint. Record the BAS SA setpoint. Observe the SA meet setpoint. c) Overwrite a zone space temp to be 10F below its setpoint. Observe the SA meet setpoint. <u>Reset Schedule</u> <table><tr><td></td><td><u>Worst</u></td><td><u>SA</u></td></tr><tr><td><u>SA</u></td><td><u>Zone (1)</u></td><td><u>Setpt</u></td></tr><tr><td></td><td>5F</td><td>50F</td></tr><tr><td></td><td>-10F</td><td>70F</td></tr></table> (1) Farthest zone above its setpoint)		<u>Worst</u>	<u>SA</u>	<u>SA</u>	<u>Zone (1)</u>	<u>Setpt</u>		5F	50F		-10F	70F	a) b) Setpoint goes to 50F [____]. SA temp meets 50F without excessive hunting. c) Setpoint goes to 70F [____]. SA temp meets 70F without excessive hunting. Compressors should shut OFF.	
	<u>Worst</u>	<u>SA</u>														
<u>SA</u>	<u>Zone (1)</u>	<u>Setpt</u>														
	5F	50F														
	-10F	70F														

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
12 Seq. 15		<u>TREND LOG 3. SAT Reset.</u> With all systems in normal mode, trend the five typical warmest zones space temps, the SAT and the SAT setpoint. Verify the reset schedule is being met, per procedure 12. Trend at 5 minute intervals for 48 hours, during the week. See Monitoring section at the end of this test.	Data indicates SA reset strategy is working.	
13a Seq. 16-19; 21		<u>Economizer and Fresh Air Control.</u> Method 1, when OSAT is <65F. a) Using a psychrometer or calibrated humidity sensor in the BAS and a psychrometric chart, determine the enthalpy of the inside (_____ Btu/lb) and outside air (_____ Btu/lb). b) With the ASU in normal mode, cause a call for cooling (if not currently calling) by changing the SAT reset parameters to call for a SAT > OSAT but < RAT, or overwrite SAT setpt. Record actions: OSAT = _____ F, RAT = _____ F; SAT setpoint = _____ F _____ c) Cause inlet vanes to open to 100% by changing all space temp. setpoints to be 20F below the current space temperatures.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
13a Seq. 16-19; 21		<p><u>Continuing from previous:</u></p> <p>d) Change the economizer changeover setpoint in the ASU to be 3 Btu/lb <u>below</u> the current OSA enthalpy, so economizer won't open.</p> <p>e) Cause inlet vanes to close to 0% open by changing all space temp. setpoints to be 20F above the current space temperatures.</p> <p>f) Change the economizer changeover setpoint in the ASU to be 3 Btu/lb <u>above</u> the current OSA enthalpy.</p> <p>g) Change conditions or overwrite so the SAT setpoint is < OSAT. OSAT = _____F, SAT setpoint = _____F.</p> <p>Return economizer setpoint, SAT reset and space setpoints to normal.</p>	<p>Fresh Air Control:</p> <p>d) Economizer damper should go to minimum. Observe that inlet vanes are 100% open [_____]. Verify that damper minimum is according to the Fresh Air Control OSA Compensation schedule: _____% open, [_____]% open] for this inlet vane position.</p> <p>e) Economizer damper minimum should change. Observe that inlet vanes are 0% open [_____]. Verify that damper minimum is according to the Fresh Air Control OSA Compensation schedule: _____% open, [_____]% open] for this inlet vane position.</p> <p>f) Economizer damper should begin to open and maintain SAT setpoint within 1F on both sides of the current SAT deadband of +/- 4F. Damper should <u>not</u> be fully open. [_____].</p> <p>g) Economizer damper should go to full open [_____]. RA damper modulates opposite of economizer damper.</p> <p>Parameters put back to normal.</p>	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
13b Seq. 16-19; 21		<p><u>Economizer and Fresh Air Control.</u> Method 2, when OSAT is >65F.</p> <p>a) Using a psychrometer or calibrated humidity sensor in the BAS and a psychrometric chart, determine the enthalpy of the inside (____ Btu/lb) and outside air (____ Btu/lb).</p> <p>b) With the ASU in normal mode, cause a call for cooling (if not currently calling) by changing the SAT reset parameters to call for cooling or overwrite SAT setpt. Record actions: OSAT = ____F, RAT = ____F; SAT setpoint = ____F.</p> <hr/> <p>c) Cause inlet vanes to open to 100% by changing all space temp. setpoints to be 20F below the current space temperatures.</p>		
13b Seq. 16-19; 21		<p><u>Continuing from previous:</u></p> <p>d) Change the economizer changeover setpoint in the ASU to be 3 Btu/lb <u>below</u> the current OSA enthalpy, so economizer won't open.</p> <p>e) Cause inlet vanes to close to 0% open by changing all space temp. setpoints to be 20F above the current space temperatures.</p>	<p>Fresh Air Control:</p> <p>d) Economizer damper should go to minimum. Observe that inlet vanes are 100% open [____]. Verify that damper minimum is according to the Fresh Air Control OSA Compensation schedule: ____% open, [____% open] for this inlet vane position.</p> <p>e) Economizer damper minimum should change. Observe that inlet vanes are 0% open [____]. Verify that damper minimum is according to the Fresh Air Control OSA Compensation schedule: ____% open, [____% open] for this inlet vane position.</p>	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
13b Seq. 16-19; 21		<p><u>Continuing from previous:</u></p> <p>f) Change the economizer changeover setpoint in the ASU to be 3 Btu/lb <u>above</u> the current OSA enthalpy. Overwrite the SAT to be > SAT setpoint by 10F.</p> <p>Return economizer setpoint, SAT reset and space setpoints to normal.</p>	<p>f) Economizer damper should begin to open and eventually go to full open. Setpoint will not be met. Compressors will come on and economizer damper will remain fully open.</p> <p>[].</p> <p>RA damper modulates opposite of economizer damper. Parameters put back to normal.</p>	
14 Seq. 23-26; 34		<p><u>Unoccupied Night Low Limit Mode.</u></p> <p>a) With ASU in normal mode, change the schedule so unoccupied mode will begin in 5 minutes.</p> <p>b) After the ASU shuts OFF, change the RA NLL setpoint to be 10F above current RA temp. Overwrite one of the polled perimeter zone space temp. to be 1F above the space NLL heating setpoint, currently ____F.</p> <p>c) Overwrite one of the polled perimeter zone space temp. to be 3F below the space NLL heating setpoint.</p> <p>d) Change the RA NLL setpoint to be within the bias or deadband range of the current RA temp.</p> <p>e) Return schedules, NLL RA setpoint and space overwritten values to normal.</p>	<p>a) When the schedule is met, the ASU shuts OFF.</p> <p>b) ASU and boiler does not come ON.</p> <p>c) The ASU and boilers come ON. Heating coil valves operate normally. Economizer dampers are shut and exhaust fans are OFF.</p> <p>d) The ASU and boilers shut OFF.</p> <p>e) Values returned to normal.</p>	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
15 Seq. 27-30; 34		<p><u>Unoccupied Night High Limit Mode.</u></p> <p>a) With ASU in normal mode, change the schedule so unoccupied mode will begin in 5 minutes.</p> <p>b) After the ASU shuts OFF, change the RA NHL setpoint to be 10F below current RA temp. Change the space NHL cooling setpoint to be 65F (so no unoccupied cooling or heating is called for). Overwrite one of the polled perimeter zone space temp. to be 1F below the space temporary NHL cooling setpoint, currently ____ F.</p> <p>c) Change economizer changeover enthalpy as necessary to allow economizer damper to open.</p> <p>d) Overwrite one of the polled perimeter zone space temp. to be 3F below the temporary space NHL cooling setpoint.</p> <p>e) Change the RA NHL setpoint to be within the bias or deadband range of the current RA temp.</p> <p>f) Return schedules, NHL RA, NHL space setpoint and space overwritten values to normal.</p>	<p>a) When the schedule is met, the ASU shuts OFF.</p> <p>b) ASU does not come ON.</p> <p>c; d) The ASU comes ON and economizer goes above minimum. Exhaust fans and boiler remain OFF.</p> <p>e) The ASU shuts OFF.</p> <p>f) Values returned to normal.</p>	
16 Seq. 23-26		<p><u>TREND LOG 4. Unoccupied NHL.</u></p> <p>During a period of weather with nights below 40F, with all systems in normal mode, trend the inlet vane position command (surrogate for ASU status), RA temp, highest and lowest polled space temp., SAT, boiler status, HWST and OSAT. Trend at 15 min. intervals for 3 days. Provide occupied schedule. See Monitoring section at the end of this test.</p>	Verify the proper sequencing per Procedure 14.	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
17 Seq. 27-30		<u>TREND LOG 5. Unoccupied NLL.</u> During a period of weather with nights below 40F, with all systems in normal mode, trend the inlet vane position command (surrogate for ASU status), RA temp, highest and lowest polled space temp., SAT, boiler status, HWST and OSAT. Trend at 15 min. intervals for 3 days. Provide occupied schedule. See Monitoring section at the end of this test.	Verify the proper sequencing per Procedure 15.	
18 Seq. 35		<u>Misc. Alarms.</u> a) Filter alarm. In the BAS, lower the filter alarm setpoint until it equals the filter differential pressure. b) Compressor failure. With an ASU compressor running, shut off the breaker to the compressor. Reset when done.	a) An alarm is registered in the BAS. b) An alarm is registered in the BAS. Breaker reset.	
19 Seq. 36		<u>External Shutdowns and Alarms.</u> a) <i>High duct static pressure.</i> In the BAS, lower the high duct static pressure alarm setpoint to the current duct static pressure. b) <i>Supply duct smoke detector.</i> Spray "smoke" on the SA duct sensor. c) <i>Return duct smoke detector.</i> Spray "smoke" on the RA duct sensor. d) Turn the <i>emergency shutdown switch</i> in on the BAS ASU controller in the Penthouse.	a) The ASU should shut OFF and register an alarm. b) The ASU should shut OFF and register an alarm in the BAS and generate a fire alarm. (see fire alarm response matrix). c) The ASU should shut OFF and register an alarm in the BAS and generate a fire alarm. (see fire alarm response matrix). d) The ASU should shut OFF and register an alarm.	
20 Seq. 37		<u>Fire Alarm Shutdown.</u> Initiate a fire alarm through the following: general smoke, pull station, sprinkler flow (jumper contacts).	All ASU's should shut OFF. General smoke alarm: _____ Pull station: _____ Sprinkler flow: _____ Duct smoke detector: (done above)	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
21 Seq. 38		Telecom Rm C-104 Interlock. a) Change schedule to be in unoccupied mode. b) Overwrite the RA temp. to be 5F less than the RA unoccupied NHL setpoint to simulate a NHL satisfied condition. c) Lower the Telecom Rm unoccupied TU-1-43 setpoint (initially 80F) to the current Telecom room space temp.	a) ASU should shut OFF and remain OFF. c) ASU should start and run, not in night high limit mode, but run until the unoccupied setpoint of TU-1-43 is satisfied.	
22 Seq. 39		BAS Monitored and Adjustable Points. Verify that the monitored and adjustable points specified in the sequences are actually operable in the BAS.	All points as per spec.	
23 Seq. 40		Terminal Boxes. Verify where in the BAS that the specified perimeter boxes are designated. Match to specs.	TU perimeter schedules match spec.	
24 Seq.		TREND LOG 6. Optimum Start. Trend the ASU static pressure (surrogate for ON condition), the OSA temperature and the average temperature used for the optimum start routine and the RA temp during weather with night time lows 30-40F, for three consecutive days in 5 minute intervals. Trend again when night time lows are 60-70F.	Observe that the start times vary per the optimum start routine and that the RA temp is met by the schedule.	
25	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedures 6, 10, 12, 16, 17, 24. Trend logs all shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Test

Project _____

FT-0201 PACKAGED BOILER And Boiler System Including HW Pumps 1 & 2

Related Tests: _____

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____

Dates of tests _____

Dates of tests _____

Dates of tests _____

2. Test Prerequisites

a. ___ The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:

___ Boiler

___ Heating water piping and valves

___ Heating water pumps

b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

_____ Controls Contractor Signature or Verbal

_____ Date

c. ___ Piping system flushing complete and required report approved.

d. ___ Water treatment system complete and operational.

e. ___ Vibration control report approved (if required).

f. ___ Test and balance (TAB) complete and approved for the hydronic system.

g. ___ All A/E punchlist items for this equipment corrected.

h. ___ These functional test procedures reviewed and approved by installing contractor.

i. ___ Safeties and operating ranges reviewed.

j. ___ Test requirements and sequences of operation attached.

k. ___ Schedules and setpoints attached.

l. ___ Sufficient clearance around equipment for servicing.

Notes:

- m. Have all energy savings control strategies, setpoints and schedules been incorporated that this boiler and control system are capable of? If not, list recommendations below.
- n. **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- o. **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- p. Record made of All Values for Current Setpoints (SPt), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accomodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒
Space Temp. Setpts		
Boiler enable OSAT setpoint		
Boiler-1: Low limit of firing rate control setpoint High limit of firing rate control setpoint Operating control setpoint Operating control setpoint differential		
Boiler-2: Low limit of firing rate control setpoint High limit of firing rate control setpoint Operating control setpoint Operating control setpoint differential		
Mixed HWT Reset	OSAT1 _____ HWT1 _____ OSAT2 _____ HWT2 _____	

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or BAS Value		Instrument Measured Value		Final Gage or BAS Value		Pass Y/N?
OSAT								
HWST (bldg loop)								
HWRT (bldg loop)								
Boiler Packaged Controls (4 sensors)		B-1	B-2	B-1	B-2	B-1	B-2	

Notes:

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
Gage temperature					
High limit control ²					
Operating control ²					
Firing rate control ²					

¹Sensor location is appropriate and away from causes of erratic operation.

²Rotate setpoint dial on each controller and compare temperature when controller clicks with the temperature gage value. Within 5F is acceptable.

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	Procedure / State	Expected Value	Site Observation	Final Values	Pass Y/N
3-way mixing valve	With one or both boilers ON, drive valve to full bypass (closed), manually or by lowering the HWST resets.	HWST = HWRT (+/- 2F)	HWST=[] HRST=[]	HWST=[] HRST=[]	
3-way mixing valve	With both boilers ON, drive valve 100% open (0% bypass, all return thru boilers), manually or by lowering the HWST resets.	HWST = boiler temp. (gage) (+/- 2F)	HWST=[] Boiler =[]	HWST=[] Boiler =[]	

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

General Conditions of Test and Seasonal Testing

The primary testing will occur during typical winter weather. Because the boiler will be operated year-round, Sequences 14-16; 20 will be trended again (Procedure 11), to ensure that boiler use is minimized during the off-season.

Notes:

6. Testing Procedures and Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Burner Control Sequencing					
1 Seq. 1; 2, 13- 14 Seq. 3 Seq 4		1) Manually shut OFF boilers and keep pumps running on manual to lower boiler water temperature to < 140F. 2) Lower the HWST reset parameters so the 3-way valve is providing 100% return, or manually fix 3-way valve to do the same. 3) If no gage, install a temperature sensor in a thermowell of the boiler. 4) With the boilers OFF, and boiler water temperature < 140F, lower the lag boiler OSAT setpoint so that the OSAT is 3F < the OSAT, so both boilers are enabled. Turn all systems to auto. Continue allowing water temp. to climb.	After (4): Both boiler isolation valves open. Both boilers start, and both [] burners of both [] boilers fire up initially at high [] fire. When temp. = 150F [], one burner bed drops to low [] fire. At 160F [], the other bed drops to low [] fire. At 170F [], the boiler shuts OFF.		
2 Seq. 5 Seq. 6 Seq. 7		Raise the HWST resets, so that the 3-way valve is at 0% return water (all thru boiler). Allow the water in the boiler to cool. Raise the HWST resets, and space temperature setpoints, as necessary, to keep boiler water cooling.	Upon cooling to 160F [], the boiler starts at low [] fire on both beds. Upon cooling to 150F [], one [] burner bed goes to high [] fire. Upon cooling to the lower setting of the Low Firing Rate Control 140F, [] the other burner goes to high fire.		
3 Seq. 14		With both boilers still running, lower the lag boiler OSAT setpoint to be 3F lower than the OSAT.	The lag boiler isolation valve closes and lag boiler and pump shuts OFF.		
Safeties					
4 Seq. 8		<u>Loss of power.</u> With boilers ON, shut OFF power to them.	Boiler burners shut OFF and an alarm is generated in the BAS.		
5 Seq. 9		<u>Low water.</u> Unhook the wire to the low water sensor to initiate an alarm.	Boiler burners shutt OFF and an alarm is generated in the BAS.		
6 Seq. 10		<u>High limit.</u> Lower the high limit setting to the current water temperature to initiate an alarm and shutdown.	Boiler burners shut OFF and an alarm is generated in the BAS.		
7 Seq. 12		<u>Flame safety.</u> Sufficiently tested during startup.	DONE		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
BAS Controlled Sequences					
8 Seq. 14		Done with procedure for Sequence 1.			
9 Seq. 13		<u>Lead Boiler.</u> Return all boiler settings and building parameters to normal. Change the lead boiler OSAT setpoint to be 3F > the OSAT.	Lead boiler starts. Only lead pump runs. Isolation valve to lag boiler is closed.		
10 Seq. 15		Continuing from the last procedure: Manually shut off the lead pump.	After 30 seconds [], the lag pump starts. No change in boiler isolation valves.		
11 Seq. 16		Return lead pump to auto. Lower the high limit setpt on boiler, until boiler goes OFF on high limit.	After 30 seconds [], the lag boiler isolation valve opens, lead valve closes and lag boiler should start.		
12 Seq. 13-14; 17; 18		<u>Trend Log.</u> Trend the OSAT, the status of both boilers and pumps, HWRT and the mixed HW supply temperature for 5 days, including a weekend at 10 minute intervals. Provide the occupied schedule for this period.	Verify Sequence 13. Verify Sequence 14. Verify Sequence 17. Verify Sequence 18.		
13 Seq. 17		<u>Unoccupied Night Low Limit Mode.</u> a) With RTU air handler (ASU) in normal mode, change the schedule so unoccupied mode will begin in 5 minutes. b) After the ASU shuts OFF, change the RA NLL setpoint to be 10F above current RA temp. Overwrite one of the polled perimeter zone space temp. to be 1F above the space NLL heating setpoint, currently ____ F. c) Overwrite one of the polled perimeter zone space temp. to be 3F below the space NLL heating setpoint. d) Change the RA NLL setpoint to be within the bias or deadband range of the current RA temp. e) Return schedules, NLL RA setpoint and space overwritten values to normal.	a) When the schedule is met, the ASU shuts OFF. b) ASU and boiler does not come ON. c) The ASU and boilers come ON. Heating coil valves operate normally. Economizer dampers are shut and exhaust fans are OFF. d) The ASU and boilers shut OFF. e) Values returned to normal.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
14 Misc.		<u>Pump speed.</u> With both boilers running, raise the space temperature setpoint in all zones to put all boxes in full heating. Wait 10 minutes to ensure that all valves are fully open. Check the amps on the pump motors. Repeat with 1 pump and 1 boiler.	Pump amps should be less than the rated full load amps x service factor of the pumps which is: _____. Actual (list each phase): P-1 _____, P-2 _____. One Pump, P-1: [_____] One Pump, P-2: [_____]		
15 Seq. 18		<u>HWST reset.</u> Using the trend log above, plot the trend data in a spreadsheet graph in the form below, or plot 20 values thru both ends of the range of trend data on the chart below.			

Notes:

MONITORING AND TREND LOGGING. Monitoring via BAS trend logs are required per test Procedures 12. Attach representative graphs or columnar data and explanatory analysis to this test report.

****Abbreviations:** HWST = mixed hot water supply temperature, BWST = boiler hot water supply temperature, SPt = setpoint, BAS = building automation system.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A summary of deficiencies identified during testing is attached

- END OF TEST -

Notes:

Functional Test

Project _____

FT-_____ **SERVICE WATER HEATER (GAS)**

Related Tests: Small Service Water Heater Circulating Pumps

1. Participants

Party

Participation

_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____

2. Test Prerequisites

a. ___ The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:

___ Hot water heaters (GWH-1 and 2) ___ Service hot water piping

b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

_____ Controls Contractor Signature or Verbal

_____ Date

c. ___ Piping system flushing complete and required report approved.

g. ___ All A/E punchlist items for this equipment corrected.

h. ___ These functional test procedures reviewed and approved by installing contractor.

i. ___ Safeties and operating ranges reviewed.

j. ___ Test requirements and sequences of operation attached.

k. ___ Schedules and setpoints attached.

l. ___ Sufficient clearance around equipment for servicing.

m. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this water heater and control system are capable of? Is the temperature setpoint as low as it could practically be?

n. ___ **Sensor Calibration Checks.** The sensors listed below checked for calibration and adequate location. This is a spot check on a sample of the calibrations done during prefunctional checklisting.*

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements. If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Notes:

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
HWST thermometer					
HWRT thermometer					

¹Sensor location is appropriate and away from causes of erratic operation.

- o. ___ Other misc. checks of the prefunctional checklist and startup reports completed successfully.
- p. ___ Record made of all values for current setpoints, etc. that may be changed to accomodate testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒
Hot water temperature setpoint GWH-1		
Hot water temperature setpoint GWH-2		

3. Testing Procedures and Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Boiler Burner Control Sequencing					
1		With the heaters in auto, but in standby, drain hot water via PRV to call for heat, or adjust the HW temperature setpoint to be 4 degrees above the HWT (from the thermometers). Flue damper should be shut.	Flue damper opens. GWH-1. GWH-2 Spark ignition lights pilot light. GWH-1 GWH-2 Main burners fire after pilot is lit. GWH-1 GWH-2		
2		--continued	When HW temperature meets setpoint, pilot & burners shut OFF; GWH-1 GWH-2 Flue damper closes. GWH-1 GWH-2		
3		<u>Power failure.</u> With WH satisfied and burner OFF, shut OFF power to flue damper.	Flue damper should open. GWH-1 GWH-2		
4		Observe the typical loop dT (HWST - HWRT).	It should be less than 8F [_____].		
5		<u>Pressure relief valve.</u> Test the pressure relief valve.	Water should be released. GWH-1 GWH-2		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
6		Inspect for flammables around WH.	There should be no flammables near WH.		
7		Does quality and quantity of makeup air appear adequate?	Appears adequate.		
8	—	Return all changed parameters & conditions to pre-test values ⁵	Check off in table of Section 2 above when completed		

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A summary of deficiencies identified during testing is attached.

— END OF TEST —

Notes:

Functional Test

Project: _____

FT-_____ SMALL SERVICE HOT WATER CIRCULATING PUMPS CP-1; 2

Related Tests: Gas HW Heaters

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing: ___ CP-1; 2
- b. ___ Boilers 1; 2 have successfully completed functional testing.
- c. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.

Controls Contractor Signature or Verbal

Date

- d. ___ All A/E punchlist items for this equipment corrected.
- e. ___ Safeties and operating ranges reviewed.
- f. ___ Test requirements and sequences of operation attached.
- g. ___ Schedules and setpoints attached.
- h. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
- i. ___ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- j. ___ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
CP-1; 2 schedule		

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓

Notes:

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

---NONE---

4. Device Calibration Checks.

---NONE---

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? 'Y' / N _____

___ Unit mounted securely.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1		Pump speed. Check the amperage of the circulating pumps.	Amperage should be less than the rated amps. Rated = _____ CP-1[] CP-2[]	
2		Change the schedule so the pumps should be OFF.	Pumps turn OFF.	
3		Schedule the pumps to be ON. Return schedule to normal.	Pumps start. Schedule returned to normal	
4	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Test

Project: _____

FT-_____ SPLIT AC UNIT AC-1; FCU-2
including
TELECOM ROOM C-104 SPACE TEMPERATURE CONTROL
Including integral equipment: ASU-4; TU-1-43
Related Tests: ASU-4

1. Participants

Party

Participation

_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 ___ AC-1; FCU-2
 ___ _____
- b. ___ TU-1-43 has successfully completed functional testing.
- c. ___ ASU-4 has successfully completed functional testing
- d. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

 Controls Contractor Signature or Verbal

 Date

- e. ___ Vibration control report approved (if required).
- f. ___ Test and balance (TAB) completed and approved for the hydronic systems and terminal units connected.
- g. ___ All A/E punchlist items for this equipment corrected.
- h. ___ These functional test procedures reviewed and approved by installing contractor.
- i. ___ Safeties and operating ranges reviewed.
- j. ___ Test requirements and sequences of operation attached.
- k. ___ Schedules and setpoints attached.

Notes:

- l. ___ False loading equipment, system and procedures ready (boilers, preheat or reheat coils, control loops, override on OSA dampers, etc.)
- m. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
- n. ___ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- o. ___ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
- p. ___ **Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:**

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
Occupied mode TU setpoint		
Unoccupied mode TU setpoint		
Occupied FCU-2 setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
Unoccupied FCU-2 setpoint		
Security Co. occupied alarm setpoint	%	%
Security Co. unoccupied alarm setpoint		
	%	%

3. **Sensor Calibration Checks.** Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
TU stat temp.		BAS:		BAS:	
FCU-2 stat temp.		Stat:		Stat:	
Security Co. Stat temp.		Stat:		Stat:	

¹Sensor location is appropriate and away from causes of erratic operation.

Notes:

4. Device Calibration Checks. The actuators or devices listed below checked for calibration. This is a spot check on a sample of the calibrations done during prefunctional checklisting and startup.

"In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

Device or Actuator & Location	Procedure / State	1st Pkg'd Value	Site Observation	Final Pkg'd Reading	Pass Y/N
TU-1-43 shall be one of the selected units in the TU functional test sample previously completed.					

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

General Conditions of Test

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		<u>TU Occupied Mode.</u> During occupied mode, verify that the TU is maintaining the space to the TU setpoint, by lowering the TU setpoint 5F and observing the TU dampers open and meet setpoint. Return TU setpoint to normal.	The new setpoint is met. (Additional testing on this TU was performed with the TU's functional testing.) Setpoint returned to normal.	
2 Seq. 1		<u>FCU-2; AC-1 Occupied Mode.</u> a) In occupied mode, lower the FCU-2 setpoint to be = current space temp. b) Lower the setpoint to 5F below the space temp. c) Lower the Security Co. setpoint to be = to the space temp. d) Return FCU-2 and Security Co. setpoints to normal.	a) FCU-2 starts. AC-1 starts and ~55F air is delivered to space. An alarm is registered in the BAS. b) FCU-2 and AC-1 run until space is cooled to new setpoint and then cycle OFF. c) An alarm is registered by the Security Co. Obtain a fax of the alarm. d) Setpoints returned to normal.	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
3 Seq. 2		<p><u>FCU-2; AC-1 Unoccupied Mode.</u> a) In unoccupied mode, lower the FCU-2 setpoint to be = current space temp.</p> <p>b) Lower the setpoint to 5F below the space temp.</p> <p>c) Lower the Security Co. setpoint to be = to the space temp.</p> <p>d) Lower the Security Co. setpoint to 5F below space temp.</p> <p>e) Return FCU-2 and Security Co. setpoints to normal.</p>	<p>a) FCU-2 starts. AC-1 starts and ~55F [] air is delivered to space. An alarm is NOT registered in the BAS.</p> <p>b) FCU-2 and AC-1 run until space is cooled to new setpoint and then cycle OFF.</p> <p>c) An alarm is registered by the Security Co. and by the BAS. Obtain a fax of the alarm. ASU-4 starts and TU delivers ~55F [].</p> <p>d) TU and FCU-2 deliver air until the Security Co. setpoint is met; then ASU-4 shuts OFF.</p> <p>e) Setpoints returned to normal.</p>	
4		<u>Low Temp. Operation.</u> During outdoor weather between 20F and 30F, verify that the unit functions and does not shut down on safeties.	Unit operates at specified low ambient temperatures.	
5 Seq. 1; 2		<u>TREND LOG 1.</u> During near design conditions in summer, trend the OSAT, TU-1-43 space temp., ASU-4 status and BAS alarms, in 15 min. intervals for 3 days.	Verify proper functioning of system per sequences and above test parameters.	
6	—	Return all changed control parameters and conditions to their pre-test values⁵	Check off in Section 2 above when completed	

MONITORING AND TREND LOGGING. Five monitoring via BAS trend logs are required per test Procedure 4. Trend logs none shall be provided in electronic continuous columnar spreadsheet compatible format. Trends all shall be provided in hard tabular format (continuous columnar with time in left column and at least four columns of point values in adjacent columns). All points for a given trend will begin at exactly the same time. Provide a key to all abbreviations. Attach representative graphs or columnar data and explanatory analysis to this test report.

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Test (Cover Sheet)

Project _____

FT-_____ TERMINAL UNITS (VAV w/ hot water reheat, single duct) DATA COMMON FOR ALL UNITS

1. Participants (fill out once, to cover all TU's)

Party	Participation	Party	Participation
_____	_____	_____	_____
_____	_____	_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____ Dates of tests _____

2. Test Prerequisites (fill out once, to cover all TU's)

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved:
- ___ All terminal units, except _____
 - ___ All air handlers serving terminal units, except _____
 - ___ Hot water pumps
- b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.
- _____ Controls Contractor Signature or Verbal _____ Date
- c. ___ Piping system flushing complete, water treatment system complete and required report approved.
- d. ___ Airside test and balance calibration of BAS readings of TU flows complete (system total flow need not be complete).
- e. ___ All A/E punchlist items for this equipment corrected.
- f. ___ These functional test procedures reviewed and approved by installing contractor.
- g. ___ Test requirements and sequences of operation attached.
- h. ___ Schedules and setpoints attached.
- i. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this TU and control system are capable of? If not, list recommendations below.
- j. ___ The controller & actuator runtime accumulator set to 0 after prefunctional checkout of the entire system.
- k. ___ Obtain and review the full program of 5% (randomly chosen) of all TU's of each type (parameters & setpoints, etc.). Examine variances. Clarify as needed, reconcile and document differences with controls contractor. If too many corrections exist with this sample, controls contractor shall recheck all programming.

3. Sampling and Additional Testing.

The terminal unit testing requirements in the specifications call for a random sample of _____% of all TU's of each type to be tested. Total number to be tested of this type = _____. The specifications also require that if _____% of the sampled TU's fail in the testing (any No Pass items), then another _____% of the total population must be tested. This applies to the subsections of the test, i.e., if sub-sections fail, only subsections of additional TU's need to be tested. Record results in the table below.

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
I. Sensor calibration		
II. Actuator calibration		
III. Static inspections		

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
IV. Programming		
V. Functional tests		

4. Testing of TU 3-Way Valves

All TU 3-way heating valves shall be verified to have been programmed and setup properly. When programmed or wired backwards, the valve will open when being commanded to close, causing the space to overheat. To verify proper wiring and programming, during a period of general cooling, verify that the actual space temperature is within 2F of the (setpoint plus any user adjustment), unless in a fluctuating area (entry, etc.). Space temperatures more than 2F above the net setpoint indicate possible 3-way valve problems. Investigate.

TU Space Temperature Control for TU's With Three-Way Valves

TU ID	Actual Space Temp.	Setpoint	User Adjust-ment	OK?

TU ID	Actual Space Temp.	Setpoint	User Adjust-ment	OK ?

Notes:

Functional Test Record

Project _____

FT-_____ **TERMINAL UNIT** _____ (VAV w/ hot water reheat, single duct)

Common values for all terminal units are recorded on the Cover Sheet. The following five pages of procedures are to be filled out for each TU tested.

Seasonal Testing and General Conditions of Test

Air handler or rooftop unit and boiler (if applicable) should be running in normal and occupied mode, unless noted. The tests may be performed in any season, if any temperature lockouts can be overridden.

Testing Procedures and Record

____ Computer printout or list made and attached of the current TU setpoints and control parameters and schedules, lockouts, etc. of other systems that may be changed to accommodate testing.

I. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
Space temp.					

¹ Sensor location is appropriate and away from causes of erratic operation.

II. Device Calibration Checks. Check the actuators or devices listed below for calibration. "In calibration" means observing a readout in the BAS and going to the actuator or controlled device and verifying that the BAS reading is correct. For items out of calibration or adjustment, fix now if easy, via an offset in the BAS, or a mechanical fix.

HCV: Set pumps to normal mode. Procedure 1. Command valve to a few intermediate positions. Verify that reading in BAS reasonably correspond to the actual positions. For heating coil valves (NO): Procedure 2a. Set heating setpoint 20°F above room temperature. Verify BAS reading says 100% open. Visually verify valve is fully open. 2b. Remove control air or electricity from the valve and verify that the valve stem and actuator position do not change. Procedure 3. Restore to normal. Set heating setpoint to 20°F below room temperature. Observe the valve close. 4. For pneumatic actuators, by override in the EMS, increase pressure to valve by 3 psi (do not exceed actuator rating). Verify valve stem & actuator position does not change. Restore to normal.

Damper or Flow: --Checked during Functional Testing Section.

Device or Actuator & Location	Procedure / State	BAS Value	Site Observation	Corrections	Pass Y/N
Heating coil valve (HCV) position or command and stroke	1. Intermediate positions				
	2a. Full open				
	2b. Remove power or air (full open)				
	3. Closed				
	4. Increase pressure (close)				

Proced . No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
III. STATIC INSPECTIONS				
1.		Verify sufficient clearance around equipment for servicing.		
2.		Verify installation of specified sound wrapping and joint sealant.		
3.		Unit secured per spec.		
4.		Model and tag checked against plans & equipment list. TU & valve tags affixed.		
5.		Verify that inlet conditions are OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, else airflow straighteners.		
6.		(Verify for only 1/2 of the tested TU's) For autoflow control valves, with water system in normal, check pressure drop across valve. Compare with valve requirements.	Pressure drop should be in the range of _____ to _____ psi [_____]. If out of range, investigate.	
7.		(Verify for the other 1/2 of the tested TU's that didn't have valve pressure drops checked.) Valve off TU. Remove and check strainer for cleanliness..	To pass, <u>basket</u> strainers must have an unclogged area >= 80% of the strainer area. <u>In-line</u> strainers with area = to pipe cross section must be 90% clean.	
8.		<u>Auto TU Diagnostics.</u> In the control system diagnostics, check the controller and actuator accumulated run times, the moving avg. flow error and moving avg. space temp. deviation from setpoint.	The ratio of actuator to controller runtime should be ideally < 3% & < 5% is acceptable. [_____%]. Moving avg. flow error should be < 10% of max. cooling cfm [_____%]. The moving avg. space temp. deviation should be < 3F [____F].	
IV. CONTROL PROGRAMMING. In the procedures of this section, compare specified written sequences and parameters with that found programmed in the TU or BAS. Variances that, in the CA's opinion, reduce performance, must be corrected. Variances that make no difference or enhance performance pass. Document all variances.				
9.		Control drawing sequences of operation	Per spec and detail adequate.	
10.		Verify that the TU address matches the TU location and ID on the plan drawings and control drawings.	Address matches.	
11.		Verify that the TU max and min setpoints in the BAS match (within 10%) the latest plan drawings and balance report (TAB).	<u>Cooling:</u> Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____ <u>Heating:</u> Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____	
12.		Verify that BAS TU K factor is within 20% of K on the submitted control drawings, unless explained by TAB.	Drawing K = _____ BAS K = [_____] TAB K = _____	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
13.		Temperature adjustment range by tenants (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
14.		Cooling-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
15.		Heating-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
16.		Unoccupied zone temperature setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
17.		Occupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
18.		Unoccupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
19.		Heating coil valve stroke time (for incremental valves)	Actual timed _____ Input found in BAS _____	
20.		Cooling space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
21.		Heating space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
22.		Cooling cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
23.		Duct area (sf)	From prints _____ Found [_____]	
24.		Damper stroke time (Spec'd value comes from controller spec, unless oval duct, which should then be timed)	Spec'd _____ Found [_____]	
25.		Auto-zero function schedule set and enabled.	Set and enabled.	
26.				
V. FUNCTIONAL TESTING.				
27.		CFM Capacity Test, Cooling. With the duct SP setpoint being met, lower the space temp. setpoint 20F. Verify in the BAS that the specified max. cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to max. as expected.	Specified max. cooling cfm = _____ Achieved cfm or position= [_____] Within deadband? _____	
28.		CFM Capacity Test, Heating. With the duct SP setpoint being met, raise the space temp. setpoint 20F. Verify in the BAS that the specified min. or heating cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to min. as expected.	Specified min. or heating cfm = _____ Achieved cfm or position= [_____] Within deadband? _____	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
29.		<i>(Verify for only 1/2 of the tested TU's)</i> <u>Warmup cycle--heating.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F above space.	Does the TU damper go to heating minimum? Does HCV go to full open?	
30.		<i>(Verify for only 1/2 of the tested TU's)</i> <u>Warmup cycle--cooling.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F below space.	Does the TU damper go to cooling maximum?	
31.		<u>HCV leakage. Method 1.</u> Use any of three methods. With the TU in cooling, with the damper in a stable position, using matched sensors, measure the duct air temperature within 4 ft. upstream and downstream of the coil.	Upstream: ____ F Down: ____ F The temperature down stream should not be warmer than the air up stream. If more than 1.0F greater, unit fails. Investigate.	
32.		<u>HCV leakage. Method 2.</u> Use any of three methods. Turn off the air handler during test. Command HCV open. After 5 min., slide temp. sensor 3/4" underneath insulation near actuated valve. Shut isolation valves to stop flow. Record ambient & initial pipe temp. and temp. after 10 min. Open isolation valves, allow temp. to reach within 3F of initial temp. and record pipe and ambient temp. Command HCV closed. Record temp. after 10 min.	<u>Isolation valves closed (no flow):</u> Ambient=____ F. Initial pipe=____ F @ 10 min=____ F. T. drop = ____ F <u>Isolation valves open, HCV closed:</u> Ambient=____ F. Initial pipe=____ F @ 10 min=____ F. T. drop = ____ F Isolation valves closed T. drop <i>minus</i> isolation valves open T. drop must be <i>less than</i> +2F [____], else valve is leaking.	
33.		<u>HCV leakage. Method 3.</u> Use any of three methods. With the heating water system in normal and the TU in full cooling, close coil supply isolation valve, open air bleed cap, open drain-down cock and drain water from coil. Return all to normal. This method is not applicable for 3-way valves.	Water should stop draining, else there may be a leak through the control valve.	
34.		<u>Unoccupied Mode--Night Low Limit.</u>		
35.		<u>Unoccupied Mode--Night High Limit.</u>		
36.		<u>Trending: HCV and Damper Control.</u> Over an 8 hour occupied period, trend at 1 min. intervals, the HCV position, the HCV command, the damper position or cfm, the damper or cfm command, the space temperature and the duct static pressure at the controlling sensor.	Compare to the space temperature to the setpoint. Observe that there is little or no overshoot of space temperature or hunting of the damper or valve.	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
37.		<i>(Trend for only 1/2 of the tested TU's)</i> <u>Trending.</u> Over a 3 day period, during near design conditions for heating and cooling, trend space temp. at 10 minute intervals. Omit this test if auto diagnostics has a moving avg. space temp. deviation log and it was completed.	Observe that the space temp. does not drift more than 1°F outside the deadband range around the setpoint.	
38.	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in program printout when completed	

MONITORING AND TREND LOGGING

Monitoring via BAS trend logs are required for test procedures 36; 37. Attach representative graphs or columnar data and explanatory analysis to this test report. The data should have time down the left column and four to six columns of parameters to the right. Provide a key to all abbreviations and attach setpoints and schedules for all trended parameters.

****Abbreviations:** BAS = building automation system, CA = commissioning agent, HCV = heating coil valve, TU = terminal unit, SA = supply air, plan drawing = building drawings and schedules from design engineer.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

— END OF TEST —

Notes:

Functional Test (Cover Sheet)

Project _____

FT-_____ TERMINAL UNITS (VAV Dual Duct, no coil) DATA COMMON FOR ALL UNITS

1. Participants (fill out once, to cover all TU's)

Party	Participation	Party	Participation
_____	_____	_____	_____
_____	_____	_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____ Dates of tests _____

2. Test Prerequisites (fill out once, to cover all TU's)

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved:
 - ___ All terminal units, except _____
 - ___ All air handlers serving terminal units, except _____
- b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

_____ Controls Contractor Signature or Verbal

_____ Date
- c. ___ Airside test and balance calibration of BAS readings of TU flows complete (system total flow need not be complete).
- d. ___ All A/E punchlist items for this equipment corrected.
- e. ___ These functional test procedures reviewed and approved by installing contractor.
- f. ___ Test requirements and sequences of operation attached.
- g. ___ Schedules and setpoints attached.
- h. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this TU and control system are capable of? If not, list recommendations below.
- i. ___ The controller & actuator runtime accumulator set to 0 after prefunctional checkout of the entire system.
- j. ___ Obtain and review the full program of 5% (randomly chosen) of all TU's of each type (parameters & setpoints, etc.). Examine variances. Clarify as needed, reconcile and document differences with controls contractor. If too many corrections exist with this sample, controls contractor shall recheck all programming.

3. Sampling and Additional Testing.

The terminal unit testing requirements in the specifications call for a random sample of _____% of all TU's of each type to be tested. Total number to be tested of this type = _____. The specifications also require that if _____% of the sampled TU's fail in the testing (any No Pass items), then another _____% of the total population must be tested. This applies to the subsections of the test, i.e., if sub-sections fail, only subsections of additional TU's need to be tested. Record results in the table below.

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
I. Sensor calibration		
II. Actuator calibration		
III. Static inspections		

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
IV. Programming		
V. Functional tests		

Functional Test Record

Project _____

FT-_____ **TERMINAL UNIT** _____ (DD, VAV Dual Duct)

Common values for all terminal units are recorded on the Cover Sheet. The following pages of procedures are to be filled out for each TU tested.

Seasonal Testing and General Conditions of Test

Air handler or rooftop unit and boiler (if applicable) should be running in normal and occupied mode, unless noted. The tests may be performed in any season, if any temperature lockouts can be overridden.

Testing Procedures and Record

____ Computer printout or list made and attached of the current TU setpoints and control parameters and schedules, lockouts, etc. of other systems that may be changed to accommodate testing.

I. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
Space temp.					

¹ Sensor location is appropriate and away from causes of erratic operation.

II. Device Calibration Checks.

1. Heating Damper Minimum Positive Closure Verification. For terminal units with a 0 (zero) cfm minimum heating cfm setpoint: With hot and cold decks operating, lower the space temperature setpoint 20F. Visually verify that the heating damper is shut tight and feel that no warm air is passing through damper. If damper is not accessible, close the return air isolation damper, measure the temperature at the cold duct inlet to the box and compare to the temperature at the discharge. If discharge temperature is more than 0.5F greater than the cooling inlet, leakage may be occurring and the unit fails this test. **PASS? (Y/N)** _____

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
III. STATIC INSPECTIONS				
1.		Verify sufficient clearance around equipment for servicing.		
2.		Verify installation of specified sound wrapping and joint sealant.		
3.		Unit secured per spec.		
4.		Model and tag checked against plans & equipment list. TU & valve tags affixed.		
5.		Verify that inlet conditions are OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, else airflow straighteners.		

Proced . No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
6.		<u>Auto TU Diagnostics.</u> In the control system diagnostics, check the controller and actuator accumulated run times, the moving avg. flow error and moving avg. space temp. deviation from setpoint.	The ratio of actuator to controller runtime should be ideally < 3% & < 5% is acceptable. [_____]%. Moving avg. flow error should be < 10% of max. cooling cfm [_____]%. The moving avg. space temp. deviation should be < 3F [_____]F.	
IV. CONTROL PROGRAMMING. In the procedures of this section, compare specified written sequences and parameters with that found programmed in the TU or BAS. Variances that, in the CA's opinion, reduce performance, must be corrected. Variances that make no difference or enhance performance pass. Document all variances.				
7.		Control drawing sequences of operation	Per spec and detail adequate.	
8.		Verify that the TU address matches the TU location and ID on the plan drawings and control drawings.	Address matches.	
9.		Verify that the TU max and min setpoints in the BAS match the latest plan drawings and balance report (TAB).	<u>Cooling:</u> Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____ <u>Heating:</u> Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____	
10.		Temperature adjustment range by tenants (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
11.		Cooling-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
12.		Unoccupied zone temperature setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
13.		Occupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
14.		Unnucupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
15.		Cooling space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
16.		Heating space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
17.		Cooling cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
18.		Heating cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
19.		Auto-zero function schedule set and enabled.	Set and enabled.	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
20.		Duct area at flow station (sf)	Clg: Prints _____ Found [_____] Htg: Prints _____ Found [_____]	
21.		Verify that BAS TU K factor is within 20% of K on the submitted control drawings, unless explained by TAB.	Cooling: Drawing K = _____ BAS K = [_____] TAB K = _____ Heating: Drawing K = _____ BAS K = [_____] TAB K = _____	
22.		Damper stroke time (Spec'd value comes from controller spec, unless oval duct, which should then be timed)	Spec'd _____ Found [_____]	
23.				
V. FUNCTIONAL TESTING.				
24.		<u>CFM Capacity Test, Cooling.</u> For TU's controlled from DDC flow stations: With the duct SP setpoint being met, lower space setpoint 20F and observe in BAS that cooling flow goes to maximum and heating flow goes to minimum. For TU's controlled by damper position only, observe that the damper goes to min. and max. as expected.	Specified max. cooling cfm = _____ Achieved cfm or position= [_____] Within deadband (if DDC)? _____ Specified min. heating cfm = _____ Achieved cfm or position = [_____] Within deadband? (if DDC) _____	
25.		<u>CFM Capacity Test, Heating.</u> For TU's controlled from DDC flow stations: With the duct SP setpoint being met, raise space setpoint 20F and observe in BAS that heating flow goes to maximum and cooling flow goes to minimum. For TU's controlled by damper position only, observe that the damper goes to min. and max. as expected. Return setpoints to normal.	Specified max. htg cfm = _____ Achieved cfm or position= [_____] Within deadband (if DDC)? _____ Specified min. clg cfm = _____ Achieved cfm or position = [_____] Within deadband? (if DDC) _____	
26.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--heating.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F above space.	Does the TU damper go to heating minimum?	
27.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--cooling.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F below space.	Does the TU damper go to cooling maximum?	
28.		<u>Interlocks.</u> This unit is interlocked with radiant panel or fin tube heating (Y/N) _____. If Yes, the fin tube or radiant panel functional tests will verify the interlocks with the TU.	TU operates normally during cycling ON and OFF of radiant panels and fin tubes.	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
29.		<p><u>Night High Limit Operation.</u> Schedule the space so it is in unoccupied mode. Change the NHL setpoint (_____) so it engages the NHL functions. _____</p> <p>a. Change the zone unoccupied setpoint to be 20F below the space temp. Observe in BAS that cooling flow goes to maximum and heating flow goes to minimum.</p> <p>b. Change the zone unoccupied setpoint (if used, else use occupied setpoint) to be = to the space temp. Observe in the BAS that the cooling and heating flows go to min.</p> <p>For TU's controlled by damper position only, observe that the dampers go to their expected positions.</p>	<p>a. Specified max. unoccupied cooling cfm = _____</p> <p>Achieved cfm or position = [_____]</p> <p>Within deadband (if DDC)? _____</p> <p>Specified min. heating cfm = _____</p> <p>Achieved cfm or position = [_____]</p> <p>Within deadband? (if DDC) _____</p> <p>b. Cooling and heating flows or positions go to minimum. [_____]</p> <p>c. TU remains in normal mode until NHL setpoint minus offset is reached by the determining zones, when AHU and TU will shut down.</p>	
30.		<p><u>Night Low Limit Operation.</u> Schedule the space so it is in unoccupied mode. Change the NLL setpoint (_____) so it engages the NLL functions. _____</p> <p>a. Change the zone unoccupied setpoint (if used, else use occupied setpoint) to be 20F above the space temp. Observe in BAS that heating flow goes to maximum and cooling flow goes to minimum.</p> <p>b. Change the zone unoccupied setpoint to be = to the space temp. Observe in the BAS that the cooling and heating flows go to min.</p> <p>For TU's controlled by damper position only, observe that the dampers go to their expected positions.</p>	<p>a. Specified max. unoccupied heating cfm = _____</p> <p>Achieved cfm or position = [_____]</p> <p>Within deadband (if DDC)? _____</p> <p>Specified min. cooling cfm = _____</p> <p>Achieved cfm or position = [_____]</p> <p>Within deadband? (if DDC) _____</p> <p>b. Cooling and heating flows or positions go to minimum. [_____]</p> <p>c. TU remains in normal mode until NLL setpoint + offset is reached by the determining zones, when AHU and TU will shut down.</p>	
31.		<p><u>Trending: Damper Control.</u></p> <p>Over an 8 hour occupied period, trend at 1 min. intervals, the hot and cold damper positions or cfm, the dampers or cfm commands, the space temperature and the duct static pressure at the controlling sensor.</p>	Compare to the space temperature to the setpoint. Observe that there is little or no overshoot of space temperature or hunting of the damper.	
32.		<p><i>(Trend for only 1/2 of the tested TU's)</i></p> <p><u>Trending General.</u> Over a 3 day period, during near design conditions for heating and cooling, trend space temp. at 10 minute intervals.</p> <p>Omit this test if auto diagnostics has a moving avg. space temp. deviation log and it was completed.</p>	Observe that the space temp. does not drift more than 1°F outside the deadband range around the setpoint.	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
33.				
34.	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in program printout when completed	

MONITORING AND TREND LOGGING

Monitoring via BAS trend logs are required for test procedures 31 and 32. Attach representative graphs or columnar data and explanatory analysis to this test report. The data should have time down the left column and four to six columns of parameters to the right. Provide a key to all abbreviations and attach setpoints and schedules for all trended parameters.

****Abbreviations:** BAS = building automation system, CA = commissioning agent, HCV = heating coil valve, TU = terminal unit, SA = supply air, plan drawing = building drawings and schedules from design engineer.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

— END OF TEST —

Notes:

Project _____

Functional Test Record

Project _____

FT-_____ **TERMINAL UNIT** _____ (VAV Dual Duct with Series Fan, no coil)

Common values for all terminal units are recorded on the Cover Sheet. The following pages of procedures are to be filled out for each TU tested.

Seasonal Testing and General Conditions of Test

Air handler or rooftop unit and boiler (if applicable) should be running in normal and occupied mode, unless noted. The tests may be performed in any season, if any temperature lockouts can be overridden.

Testing Procedures and Record

____ Computer printout or list made and attached of the current TU setpoints and control parameters and schedules, lockouts, etc. of other systems that may be changed to accomodate testing.

I. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
Space temp.					

¹ Sensor location is appropriate and away from causes of erratic operation.

II. Device Calibration Checks.

1. Heating Damper Minimum Positive Closure Verification. For terminal units with a 0 (zero) cfm minimum heating cfm setpoint: With hot and cold decks operating, lower the space temperature setpoint 20F. Visually verify that the heating damper is shut tight and feel that no warm air is passing through damper. If damper is not accessible, close the return air isolation damper, measure the temperature at the cold duct inlet to the box and compare to the temperature at the discharge. If discharge temperature is more than 0.5F greater than the cooling inlet, leakage may be occurring and the unit fails this test. **PASS? (Y/N)** _____

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
III. STATIC INSPECTIONS				
1.		Verify sufficient clearance around equipment for servicing.		
2.		Verify installation of specified sound wrapping and joint sealant.		
3.		Unit secured per spec.		
4.		Model and tag checked against plans & equipment list. TU & valve tags affixed.		

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
5.		Verify that inlet conditions are OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, else airflow straighteners.		
6.		Visually verify that the return air isolation or balancing damper is open.		
7.		<u>Auto TU Diagnostics.</u> In the control system diagnostics, check the controller and actuator accumulated run times, the moving avg. flow error and moving avg. space temp. deviation from setpoint.	The ratio of actuator to controller runtime should be ideally < 3% & < 5% is acceptable. [_____]%. Moving avg. flow error should be < 10% of max. cooling cfm [_____]%. The moving avg. space temp. deviation should be < 3F [_____]F.	
IV. CONTROL PROGRAMMING. In the procedures of this section, compare specified written sequences and parameters with that found programmed in the TU or BAS. Variances that, in the CA's opinion, reduce performance, must be corrected. Variances that make no difference or enhance performance pass. Document all variances.				
8.		Control drawing sequences of operation	Per spec and detail adequate.	
9.		Verify that the TU address matches the TU location and ID on the plan drawings and control drawings.	Address matches.	
10.		Verify that the TU max and min setpoints in the BAS match the latest plan drawings and balance report (TAB).	Cooling: Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____ Heating: Drawing max = _____ min = _____ BAS max = [_____] min = [_____] TAB max = _____ min = _____	
11.		Temperature adjustment range by tenants (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
12.		Cooling-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
13.		Unoccupied zone temperature setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
14.		Occupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
15.		Unoccupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
16.		Cooling space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
17.		Heating space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
18.		Cooling cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
19.		Heating cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found [_____]	
20.		Auto-zero function schedule set and enabled.	Set and enabled.	
21.		Duct area at flow station (sf)	Clg: Prints _____ Found [_____] Htg: Prints _____ Found [_____]	
22.		Verify that BAS TU K factor is within 20% of K on the submitted control drawings, unless explained by TAB.	Cooling: Drawing K = _____ BAS K = [_____] TAB K = _____ Heating: Drawing K = _____ BAS K = [_____] TAB K = _____	
23.		Damper stroke time (Spec'd value comes from controller spec, unless oval duct, which should then be timed)	Spec'd _____ Found [_____]	
24.				

V. FUNCTIONAL TESTING.

25.		<u>Occupied CFM Test & Fans, Cooling.</u> For TU's controlled from DDC flow stations: a. During occupied mode with only a few lights ON in the zone and with the duct SP setpoint being met, lower space setpoint 20F and observe in BAS that cooling flow goes to maximum and heating flow goes to minimum. b. Turn OFF all lights in the zone. For TU's controlled by damper position only, observe that the damper goes to min. and max. as expected.	a. Fan is ON. Specified max. cooling cfm = _____ Achieved cfm or position = [_____] Within deadband (if DDC)? _____ Specified min. heating cfm = _____ Achieved cfm or position = [_____] Within deadband? (if DDC) _____ b. Fan turns OFF. [_____] Flows remain under previous control control. [_____]	
26.		<u>Occupied CFM Test & Fans, Heating.</u> For TU's controlled from DDC flow stations: a. During occupied mode with only a few lights ON in the zone and with the duct SP setpoint being met, raise space setpoint 20F and observe in BAS that heating flow goes to maximum and cooling flow goes to minimum.	a. Fan is ON. Specified max. htg cfm = _____ Achieved cfm or position = [_____] Within deadband (if DDC)? _____ Specified min. clg cfm = _____ Achieved cfm or position = [_____] Within deadband? (if DDC) _____	
27.		--continuing: b. Turn OFF all lights in zone. For TU's controlled by damper position only, observe that the damper goes to min. and max. as expected. Return setpoints to normal.	b. Fan turns OFF. [_____] Flows remain under previous control control. [_____]	

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
28.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--heating.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F above space.	TU damper goes to heating min. [_____] Fan is ON. [_____]	
29.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--cooling.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F below space.	TU damper goes to cooling max. [_____] Fan is ON. [_____]	
30.		<u>Interlocks.</u> This unit is interlocked with radiant panel or fin tube heating (Y/N) _____. If Yes, the fin tube or radiant panel functional tests will verify the interlocks with the TU.	TU operates normally during cycling ON and OFF of radiant panels and fin tubes.	
31.		<u>Unoccupied & Night High Limit Operation.</u> a. <u>Fans.</u> Schedule the space so it is in unoccupied mode. Turn all lights OFF in the zone. Observe that the fan is OFF. b. Turn a few lights ON in zone. Change the NHL setpoint (_____) so it engages the NHL. _____	a. Fan is OFF. [_____] b. Fan is OFF. [_____]	
32.		--cont. <u>Unoccupied & Night High Limit.</u> c. Change the zone unoccupied setpoint to be 20F below the space temp. Observe in BAS that cooling flow goes to maximum and heating flow goes to minimum. d. Change the zone unoccupied setpoint to be = to the space temp. Observe in the BAS that the cooling and heating flows go to min. For TU's controlled by damper position only, observe that the dampers go to their expected positions.	c. Specified max. unoccupied cooling cfm = _____ Achieved cfm or position = [_____] Within deadband (if DDC)? _____ Specified min. heating cfm = _____ Achieved cfm or position = [_____] Within deadband? (if DDC) _____ Fan is OFF. [_____] d. Cooling and heating flows or positions go to minimum. [_____] Fan is OFF. [_____] e. TU remains in normal mode until NHL setpoint minus offset is reached by the determining zones, when AHU and TU will shut down.	

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
33.		<p><u>Unoccupied & Night Low Limit Operation.</u> a. <u>Fans.</u> Schedule the space so it is in unoccupied mode. Turn ON some lights in the space. Observe that the fan is OFF. Change the NLL setpoint (____) so it engages the NLL functions. _____</p> <p>b. Change the zone unoccupied setpoint (if used, else use occupied) to be 20F above the space temp. Observe in BAS that heating flow goes to maximum and cooling flow goes to minimum.</p> <p>c. Change the zone unoccupied setpoint (if used, else use occupied setpoint) to be = to the space temp. Observe in the BAS that the cooling and heating flows go to min. For TU's controlled by damper position only, observe dampers go to expected positions.</p>	<p>a. Fan is OFF. [____]</p> <p>b. Specified max. unoccupied heating cfm = _____ Achieved cfm or position = [____] Within deadband (if DDC)? _____ Specified min. cooling cfm = _____ Achieved cfm or position = [____] Within deadband? (if DDC) _____ Fan is OFF. [____]</p> <p>c. Cooling and heating flows or positions go to minimum. [____] Fan is OFF. [____]</p> <p>d. TU remains in normal mode until NLL setpoint + offset is reached by the determining zonés, when AHU and TU will shut down.</p>	
34.		<p><u>Backflow into RA Check.</u> In occupied mode, with fan ON and return air damper open, lower the space temp. setpoint 20F. Wait until the cooling flow goes to maximum and remains fairly constant.</p> <p>Measure flows on all diffusers with a flow hood. (This test may be omitted if the TAB conducted and documented this procedure in a satisfactory manner on all fan powered TU's.)</p>	<p>BAS cooling max. design = _____. Box design = _____. Fan spec'd cfm = _____. Sum of diffusers = [____]. Actual cooling flow = [____]. Actual heating flow = [____]. Htg flow + clg flow = [____]. This should be within 10% of box design [____] and less than or equal to the sum of all diffuser flows, else some flow is backing into RA and test fails (fan is undersized).</p>	
35.		<u>Alarms.</u> With fan ON, flip OFF fan switch.	An alarm is registered in the BAS.	
36.		<p><u>Trending: Damper Control and Fans.</u></p> <p>Over an 8 hour occupied period, trend at 1 min. intervals, the hot and cold damper positons or cfm, the dampers or cfm commands, the space temp., fan status, lighting status and the duct static pressure at the controlling sensor.</p>	<p>Compare to the space temperature to the setpoint. Observe that there is little or no overshoot of space temperature or hunting of the damper.</p> <p>Fan is OFF during unoccupied hours OR when lights are OFF.</p>	

Notes:

Proced . No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
37.		<i>(Trend for only 1/2 of the tested TU's)</i> <u>Trending, Space Temp.</u> Over a 3 day period, during near design conditions for heating and cooling, trend space temp. at 10 min. steps. Omit the space temp. trend if auto diagnostics has a moving avg. space temp. deviation log and it was completed.	Observe that the space temp. does not drift more than 1°F outside the deadband range around the setpoint.	
38.	—	Return all changed control parameters and conditions to their pre-test values⁵	Check off in program printout when completed	

MONITORING AND TREND LOGGING

Monitoring via BAS trend logs are required for test procedures 34 and 35. Attach representative graphs or columnar data and explanatory analysis to this test report. The data should have time down the left column and four to six columns of parameters to the right. Provide a key to all abbreviations and attach setpoints and schedules for all trended parameters.

****Abbreviations:** BAS = building automation system, CA = commissioning agent, HCV = heating coil valve, TU = terminal unit, SA = supply air, plan drawing = building drawings and schedules from design engineer.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

— END OF TEST —

Notes:

Functional Test (Cover Sheet)

Project _____

FT-_____ TERMINAL UNITS (VAV cooling only) DATA COMMON FOR ALL UNITS

1. Participants (fill out once, to cover all TU's)

<u>Party</u>	<u>Participation</u>	<u>Party</u>	<u>Participation</u>
_____	_____	_____	_____
_____	_____	_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____ Dates of tests _____

2. Test Prerequisites (fill out once, to cover all TU's)

a. The following have been started up and startup reports and prefunctional checklists submitted and approved:

___ All terminal units, except _____

___ All air handlers serving terminal units, except _____

b. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

_____ Controls Contractor Signature or Verbal

_____ Date

c. ___ Airside test and balance calibration of BAS readings of TU flows complete (system total flow need not be complete).

d. ___ All A/E punchlist items for this equipment corrected.

e. ___ These functional test procedures reviewed and approved by installing contractor.

f. ___ Test requirements and sequences of operation attached.

g. ___ Schedules and setpoints attached.

h. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this TU and control system are capable of? If not, list recommendations below.

i. ___ The controller & actuator runtime accumulator set to 0 after prefunctional checkout of the entire system.

j. ___ Obtain and review the full program of 5% (randomly chosen) of all TU's of each type (parameters & setpoints, etc.). Examine variances. Clarify as needed, reconcile and document differences with controls contractor. If too many corrections exist with this sample, controls contractor shall recheck all programming.

3. Sampling and Additional Testing.

The terminal unit testing requirements in the specifications call for a random sample of _____% of all TU's of each type to be tested. Total number to be tested of this type = _____. The specifications also require that if _____% of the sampled TU's fail in the testing (any No Pass items), then another _____% of the total population must be tested. This applies to the subsections of the test, i.e., if sub-sections fail, only subsections of additional TU's need to be tested. Record results in the table below.

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
I. Sensor calibration		
II. Actuator calibration		
III. Static inspections		

Sub-Section	% Failed of 1st Sample	% Failed of 2nd Sample
IV. Programming		
V. Functional tests		

Functional Test Record

Project _____

FT-_____ TERMINAL UNIT _____ (VAV cooling only)

Common values for all terminal units are recorded on the Cover Sheet. The following five pages of procedures are to be filled out for each TU tested.

Seasonal Testing and General Conditions of Test

Air handler or rooftop unit and boiler (if applicable) should be running in normal and occupied mode, unless noted. The tests may be performed in any season, if any temperature lockouts can be overridden.

Testing Procedures and Record

____ Computer printout or list made and attached of the current TU setpoints and control parameters and schedules, lockouts, etc. of other systems that may be changed to accommodate testing.

I. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____). If not, install offset in BAS, calibrate or replace sensor. Use the same test instruments as used for the original calibration, if possible.

Sensor & Location	Location OK ¹	1st Gage or BAS Value	Instrument Measured Value	Final Gage or BAS Value	Pass Y/N?
Space temp.					

¹ Sensor location is appropriate and away from causes of erratic operation.

II. Device Calibration Checks. --Checked in the Functional Testing Section.

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
III. STATIC INSPECTIONS				
1.		Verify sufficient clearance around equipment for servicing.		
2.		Verify installation of specified sound wrapping and joint sealant.		
3.		Unit secured per spec.		
4.		Model and tag checked against plans & equipment list. TU tags affixed.		
5.		Verify that inlet conditions are OK: Smooth, round, straight duct for at least 3 duct diameters when possible and 2 diameters minimum for velocity pressure sensor and 3 to 5 diameters for single point electronic sensors, else airflow straighteners.		
6.		<u>Auto TU Diagnostics.</u> In the control system diagnostics, check the controller and actuator accumulated run times, the moving avg. flow error and moving avg. space temp. deviation from setpoint.	The ratio of actuator to controller runtime should be ideally < 3% & < 5% is acceptable. [_____%]. Moving avg. flow error should be < 10% of max. cooling cfm [_____%]. The moving avg. space temp. deviation should be < 3F [____F].	

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
IV. CONTROL PROGRAMMING. In the procedures of this section, compare specified written sequences and parameters with that found programmed in the TU or BAS. Variances that, in the CA's opinion, reduce performance, must be corrected. Variances that make no difference or enhance performance pass. Document all variances.				
7.		Control drawing sequences of operation	Per spec and detail adequate.	
8.		Verify that the TU address matches the TU location and ID on the plan drawings and control drawings.	Address matches.	
9.		Verify that the TU max and min setpoints in the BAS match (within 10%) the latest plan drawings and balance report (TAB).	Cooling: Drawing max = _____ min = _____ BAS max = [] min = [] TAB max = _____ min = _____	
10.		Verify that BAS TU K factor is within 20% of K on the submitted control drawings, unless explained by TAB.	Drawing K = _____ BAS K = [] TAB K = _____	
11.		Temperature adjustment range by tenants (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
12.		Cooling-- occupied zone temp. setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
13.		Unoccupied zone temperature setpoint (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
14.		Occupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
15.		Unoccupied zone temp. bias (deadband) (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
16.		Cooling space setpoint proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
17.		Cooling cfm proportional band (indicate if a setting was spec'd)	Spec'd or reasonable value _____ Found []	
18.		Duct area (sf)	From prints _____ Found []	
19.		Damper stroke time (Spec'd value comes from controller spec, unless oval duct, which should then be timed)	Spec'd _____ Found []	
20.		Auto-zero function schedule set and enabled.	Set and enabled.	
21.				
V. FUNCTIONAL TESTING.				

Notes:

Proced No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
22.		<u>CFM Capacity Test, Cooling.</u> With the duct SP setpoint being met, lower the space temp. setpoint 20F. Verify in the BAS that the specified max. cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to max. as expected.	Specified max. cooling cfm = _____ Achieved cfm or position= [_____] Within deadband? _____	
23.		<u>CFM Capacity Test, Heating.</u> With the duct SP setpoint being met, raise the space temp. setpoint 20F. Verify in the BAS that the specified min. cfm is achieved (within deadband). For TU's controlled by damper position only, observe that the damper goes to min. as expected.	Specified min. cfm = _____ Achieved cfm or position= [_____] Within deadband? _____	
24.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--heating.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F above space.	Does the TU damper go to minimum?	
25.		(Verify for only 1/2 of the tested TU's) <u>Warmup cycle--cooling.</u> Adjust schedule or time so TU will be in warmup mode. Adjust the space setpoint to be 5F below space.	Does the TU damper go to cooling maximum?	
26.		<u>Unoccupied Mode--Night Low Limit.</u>		
27.		<u>Unoccupied Mode--Night High Limit.</u>		
28.		<u>Trending: Damper Control.</u> Over an 8 hour occupied period, trend at 1 min. intervals, the damper position or cfm, the damper or cfm command, the space temperature and the duct static pressure at the controlling sensor.	Compare to the space temperature to the setpoint. Observe that there is little or no overshoot of space temperature or hunting of the damper.	
29.		(Trend for only 1/2 of the tested TU's) <u>Trending: General.</u> Over a 3 day period, during near design conditions for heating and cooling, trend space temp. at 10 minute intervals. Omit this test if auto diagnostics has a moving avg. space temp. deviation log and it was completed.	Observe that the space temp. does not drift more than 1°F outside the deadband range around the setpoint.	

Notes:

Proced . No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response or finding in brackets or circle]	Pass Y/N & Note #
30.				
31.	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in program printout when completed	

MONITORING AND TREND LOGGING

Monitoring via BAS trend logs are required for test procedures 28; 29. Attach representative graphs or columnar data and explanatory analysis to this test report. The data should have time down the left column and four to six columns of parameters to the right. Provide a key to all abbreviations and attach setpoints and schedules for all trended parameters.

****Abbreviations:** BAS = building automation system, CA = commissioning agent, HCV = heating coil valve, TU = terminal unit, SA = supply air, plan drawing = building drawings and schedules from design engineer.

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

— END OF TEST —

Notes:

Functional Test

Project: _____

FT-_____ UNIT HEATER UH-1, Penthouse

Related Tests: Boilers

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
 Date of test _____

2. Prerequisite Checklist

- a. The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:

___ UH-1

- b. ___ Boilers 1; 2 have successfully completed functional testing.
 c. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging, loop tuning and sensor calibrations complete.

 Controls Contractor Signature or Verbal

 Date

- d. ___ All A/E punchlist items for this equipment corrected.
 e. ___ Safeties and operating ranges reviewed.
 f. ___ Test requirements and sequences of operation attached.
 g. ___ Schedules and setpoints attached.
 h. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
 i. ___ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 j. ___ **Packaged Control Program Review.** Review the packaged control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 k. ___ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Notes:

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒
UH-1 setpoint		

Parameter	Pre-Test Values	Returned to Pre-Test Values ☒

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.

"In calibration" means making a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, packaged control panel or building automation system (BAS)) compared to the test instrument-measured value is within the tolerances specified in the prefunctional checklist requirements (_____).

Sensor & Location	Location OK ¹	1st Gage or Pkg & BAS Values	Instru. Meas'd Value	Final Gage or Pkg & BAS Values	Pass Y/N?
UH-1 stat temp.		Stat:		Stat:	

¹Sensor location is appropriate and away from causes of erratic operation.

4. Device Calibration Checks.

—NONE—

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____

___ Unit mounted securely. ___ Unit accessible for servicing. ___ No unusual noise or vibration in fan.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1 Seq. 1		Adjust the stat setpoint until it is equal to the space temp.	___ Fan starts. ___ Heating coil valve opens; ___ warm air delivered.	
2 Seq. 1		Adjust the stat setpoint until it is 4F below the space temp.	Fan stops. Heating coil valve closes.	
3	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Performance Test**Variable Frequency Drive (VFD)
VAV Fan Application****Constant Static Pressure Application**

Project: _____
Address: _____

Date: _____

Commissioning Participants:

Commissioning agent: _____ of _____
EMS operator: _____ of _____
VFD technician: _____ of _____
HVAC technician: _____ of _____
Owner's rep.: _____ of _____

Air handler ID: _____. ____ Supply fan (SF) Hp: ____ CFM: ____ RPM ____ SP ____
____ Return fan (RF) Hp: ____ CFM: ____ RPM ____ SP ____

VFD brand and model: _____

The following functional performance test is for a VFD controlling a VAV air handler to a constant duct static pressure (SP). *A check-mark denotes acceptance or compliance.*

I. Design Intent and Documentation Verification

- ____ Review the design documents and the specifications.
____ Verify that the VFD ____ description, ____ specifications, ____ technical and troubleshooting guide and the installation, ____ programming record and ____ balance report are on-site.

From the design documents determine: Location of static pressure sensor:

Nearest duct fitting upstream (fitting and distance): _____

Nearest duct fitting downstream: _____

Control strategy for the return fan: _____

II. VFD Installation**Static Pressure Sensor****Linear Position**

Location of sensor in % of the distance from fan to terminal box: _____

Normally, the sensor should be located 2/3 to 3/4 the distance from the fan to the terminal box of the most restrictive branch.

____ **Complies?**

Pressure Reading Reliability

Nearest duct fitting upstream (fitting and distance): _____

Nearest duct fitting downstream: _____

The SP sensor controlling the VFD must be located so as to properly sense the static pressure in the duct without being adversely affected by changes in flow from duct fittings. This ideally requires the sensor to be at least 10 duct diameters downstream and 5 duct diameters upstream from any duct takeoff or elbow fittings.

___Complies?

Pressure Offset (Po)

Duct static pressure fan is being controlled to: _____ in. H₂O [A].

Pressure rise across supply fan at design conditions (from balance report summary): _____ in. H₂O [B]. Pressure offset, Po, [A] / [B]: _____.

Optimally, Po should be 0.3 or less in order for the VFD and fan to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the duct SP sensor is probably located too close to the fan.

___Complies?

Balancing to Lowest Pressure

Review the HVAC balance report and verify that according to the report, the system was balanced so the VFD controls to the lowest possible duct static pressure (that is, a capacity test was performed). The controlling duct static pressure from balance reports is _____ in. H₂O. The corresponding VFD frequency or fan RPM from the balance report is: supply fan (SF): _____, return fan (RF): _____. Refer to the end of this test for details of the capacity test.

___Balanced to lowest static? (this is further verified by #2 under Section IV)

Turn-Down Ratio

What is the minimum Hz the VFD will take the fan to? _____ What is the reason for any limitations? _____

General Issues

- ___ Verify that any power quality mitigation measures required from the specifications have been completed.
- ___ Verify that any inlet vanes or outlet dampers on the fan have been removed or permanently held full open.
- ___ Verify verbally that the acceleration and deceleration ramp time of the VFD is between one and four minutes.
Actual ramp time: up _____ min. down _____ min. (too short of ramp times will result in "hunting" and excess modulation by the VFD, typical ramp times are 1 to 4 minutes)
- ___ Verify that the lower frequency limit is 0, unless explained.
- ___ Verify that the VFD has been integrated into the EMS as per specification.
- ___ Verify that the EMS monitors the duct static pressure or that an in-line "T" in the static pressure hose is extended to near the VFD, from which a magnehelic static pressure reading can be made during testing.

III. Functional Performance Test

This test is not intended to verify that the VAV system is functioning properly, but rather that the VFD is functioning properly.

1. **Boxes Partially Open (intermediate CFM).** If current conditions are such, that the system is not expected to be in full cooling, nor be at the minimum flow condition:
 - a. Read the frequency output of the VFDs and record in Table 1 in the "Boxes Partially Open" column for both the supply fan (SF) and return fan (RF) if applicable.
 - b. Read the duct static pressure and record in the same column.

If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, to simulate an approaching of thermostat satisfaction and take readings.

2. **Boxes to Maximum Open (Full Cooling).** Using the (EMS) or other means, change all the space temperature setpoints to at least 10 degrees below the current space temperature so that the entire HVAC system supplied from this fan is in full cooling in all zones and *all* terminal boxes are open to their maximum "stops."
 - a. Measure or read the duct static pressure controlling the VFD and record in the "Open to Max. Stop" column in Table 1.
 - b. Read the frequency output of the VFDs and record in Table 1.
3. **Boxes to Minimum Positions.** Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum.
 - a. Take the frequency and static pressure readings and record in Column D.

IV. Analysis

Table 1.

A	B	C	D
Design static pressure _____	Terminal	Boxes	Boxes Closed
Design freq. (Hz): SF _____ RF _____	Boxes Open	Partially	to Min. Stop
Design RPM: SF _____ RF _____	to Max. Stop	Open	
SP being controlled to now _____	SF RF	SF RF	SF RF
VFD frequency. or RPM			
Static pressure during VFD test			
Static pressure during capacity test		(from TAB report data form)	

1. Fractional variance of SF design frequency or RPM to full open, $1 - (B / A)$: _____. If the full open SF frequency or RPM is more than 5% less than the design value (assuming the design and actual static are equal), all boxes may not be driven full open. Investigate as appropriate.
 ____ Less than 5% variance?

2. The SP with full open boxes (B) should be significantly less than the SP during the partially loaded conditions and should be within 0.15 inches SP of the SP from the capacity test. If the VFD SP is greater than the capacity test SP, all boxes may not be fully open. If the SP's are not close to each other, the TAB data may be inaccurate. Compliance basically verifies that a capacity test was completed.

___Complies?

3. ___Is the SP in (C) and (D) within 10% of the what it's being controlled to in (A)?

4. ___The min. turn down ratio (from Section II) should be close to (freq. D/B) Y/N?

5. ___Return fan RPMs or frequencies track well with changes in SF RPM, accounting for changes in OSA quantities and relief strategy?

6. Static pressure (SP) readings at the last two conditions should remain within 5% of each other. If there is more than a 5% variance, the sensor may be unstable, possibly from being too close to duct fittings.

___Less than 5% variance?

___Collaborative Trending: If the variance is greater than 5% and if the Pressure Reading Reliability location doesn't comply, from Section III, trending (monitoring) the SP against terminal unit damper position or SF flow is recommended to confidently verify stability. The SP should remain constant (+/- 5%) regardless of damper position or flow.. SP trended? _____

___Complies? (sensor is stable)

7. ___For the frequency or RPM readings in Table 1, are the values in Col. B > C > D?

V. Training

___The training specified in the design incentive agreement has been completed.

Required Capacity Test

To insure that energy use is minimized, the HVAC system must be balanced at design conditions at the lowest possible static pressure possible. This requires that the lowest possible static pressure (SP) be found at the sensor that will allow full design flow at the TU most difficult to satisfy. This system minimum SP found is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F, causing all terminal units (TU) to be calling for full cooling. Each TU's airflow is then measured against the design flow. The TU that is receiving the lowest fraction of design is identified. The current SP at the controlling sensor is noted. A calculation is made, giving the SP required at the sensor to allow the identified most critical TU box to meet its design flow. The equation is $SP_2 = SP_1 \times Q_2^2 / Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. SP_1 = SP at sensor. SP_2 = SP to control to. It is noted that if all boxes were calling for full cooling simultaneously, the fan could not maintain the new SP_2 value, due to diversity fan size reduction having been made by the design engineer.

Parties required for VFD site commissioning work

Commissioning agent To witness and record the tests.

EMS operator To drive boxes open and shut by changing the set points, etc.

VFD technician To use the keypad to verify the ramp time. (unless verified at start-up, which is recommended). Sequencing the keypad to display ramp time could be done by the commissioning agent, alone after reviewing the VFD technical manual.

HVAC technician To apply magnehelic gages to the pressure tap to measure duct static, if not monitored by EMS.

Functional Performance Test

Variable Frequency Drive (VFD) Pump Application

Secondary Hydronic Pump Application

Project: _____ Date: _____
Address: _____

Commissioning Participants:

Commissioning agent (CA): _____ of _____
EMS operator: _____ of _____
VFD technician: _____ of _____
HVAC technician: _____ of _____
Owner's rep.: _____ of _____

Pumps ID: _____ Chilled water (CHW) secondary, _____ Hot water (HW)
Design max.: Hp: _____ GPM: _____ Head _____ Ft

VFD brand and model: _____

The following functional performance test is for a VFD controlling a variable flow hydronic system to a constant differential pressure (DP). A *check-mark* denotes acceptance or compliance.

I. Design Intent and Documentation Verification

- ___ Review the design documents and the specifications.
 - ___ Verify that the VFD ___ description, ___ specifications, ___ technical and troubleshooting guide and the installation, ___ programming record and ___ balance report are on-site.
- From the design documents determine: Location for the DP measurement:

Control strategy for the pump: _____

II. VFD Installation

Differential Pressure Sensor

Actual location of DP measurement _____
The measurement should ideally be taken across the coil of the last branch.

Notes:

__Complies?

Pressure Offset (Po)Conversion: psi x 2.31 = ft H₂O

DP pump is being controlled to: _____feet [A].

Pressure rise across pump at design conditions (from balance report): _____feet [B].

Pressure offset, Po, [A] ÷ [B]= _____.

Optimally, Po should be 0.3 or less in order for the VFD and pump to be able to respond to small pressure changes and realize adequate energy savings. If Po is greater than 0.4, the DP sensor is probably located too close to the pump.

__Complies?

Balancing to Lowest Pressure

Review the HVAC balance report and verify, according to the report, that the system was balanced so the VFD controls to the lowest possible DP (that is a capacity test was performed). The controlling DP from balance reports is _____feet. At design, the corresponding VFD frequency or pump RPM from the balance report is: Pump-1 _____, Pump-2 _____; Pump-3 _____. The corresponding flow from the balance report is _____GPM. Refer to the capacity test at the end of this form for details.

__Balanced to lowest DP?

General Issues

- __ Verify that any power quality mitigation measures required from the specifications have been completed.
- __ Verify that there are no 3-way coil valves that may negate the value of the VFD by allowing flow to bypass the coil, except for a very small min. flow bypass.
- __ Verify verbally that the acceleration and deceleration ramp time of the VFD is between one and four minutes. Actual ramp time: up _____min. down _____min. (too short of ramp times will result in "hunting" and excess modulation by the VFD; typical ramp times are 1 to 4 minutes)
- __ Verify that each VFD has been integrated into the EMS as per specification.
- __ Verify that the lower frequency limit is programmed to 10-30% (the lower the better).
- __ Verify that the EMS monitors the DP.
- __ Min.flow bypass with 2-way or constant flow valve, if present, has flow less than 2% of design flow?

III. Functional Performance Test

This test is not intended to verify that the coil valve is functioning properly, but rather that the VFD is functioning properly.

1. **Design Flow by Test and Balance (TAB).** Record in Condition 1 in Table 1 the speed, DP and total supply flow at design conditions from the TAB report.

Notes:

2. **Intermediate Flow** (coil valves partially open). If current conditions are such, that the system is not expected to be in full cooling or full heating, nor be at minimum flow.
 - a. Read the speed, DP and the total supply flow in the secondary loop and record in Condition 3 in Table 1.

If the conditions are not in an "intermediate" position, change all space temperature set points to 4 degrees below the actual temperature in the space, for *CHW pumps* OR 4 degrees above for *HW pumps* (circle one) to simulate an approaching of thermostat satisfaction and take readings.

3. **Design Flow** (coil valves full open). Using the (EMS) or other means, change all the space temperature set points to at least 10 degrees *below* the current space temperature for *CHW pumps*, OR 10 degrees *above* for *HW pumps*, so that the entire HVAC system supplied from these pumps is in full cooling (or heating, as appropriate, circle) in all zones. Observe that all coil valves are to their *design* maximum position (from the TAB report). Wait at least 20 minutes for lag time while observing:

___ Does the first lag pump turn on (after a delay) when the lead pump exceeds its _____ gpm design flow?

___ Does the 2nd lag pump turn on (after a delay) when the sum Lead + Lag 1 exceeds the sum of their design, AND the DP drops to _____ % or _____ feet? (typically 80%)

- a. Read the speeds, DP and the total supply flow and record in Condition 2.

4. **Minimum Flow** (Coil valves shut). Change all space temperature set points to be equal to the actual space temperatures to simulate a satisfied condition, driving the boxes to their minimum and the coil valves closed. Wait at least 25 minutes.

___ Do the lag pumps sequentially turn off (with a delay) when the flow is less than the design of all *running* pumps?

___ Does the last pump shut off appropriately?

- a. Take the frequency, pressure and flow readings and record in Condition 4.

Notes:

IV. Analysis

Table 1.

Condition	Secondary Pump No.	Speed (Hz or RPM)		DP at Sensor (psi)		Total Flow (gpm)
		Reading	Average	Reading	Average	
1. At design flow by TAB	Lead					
	Lag-1					
	Lag-2					
2. At design flow (during commissioning)	Lead					
	Lag-1					
	Lag-2					
3. At intermediate flow (during commissioning)	Lead					
	Lag-1					
	Lag-2					
4. At no flow (during commissioning)	Lead					
	Lag-1					
	Lag-2					

Conversion: $0.434 \times \text{ft H}_2\text{O} = \text{psi}$, $2.31 \times \text{psi} = \text{ft H}_2\text{O}$

- In Table 1, average the speed and the DP for all pumps at each of the four conditions.
- If the speed at Condition 1 (TAB test) is not within 10% of the current test at Condition 2, all the boxes may not have been driven wide open during the Cx'g test, or the readings were taken before the lag time was complete. Investigate and repeat tests as appropriate.
☐ Less than 10% variance?
- During operation of lead-lag pump combinations, the average DP readings at all four conditions should remain within 10% of each other. If there is more than a 10% variance, the sensor may be faulty. (During lead-lag pump transition, the DP may appropriately vary by as much as 20%)
☐ Less than 10% variance?
- ☐ At no flow, Condition 4, is the flow and DP zero or equal to the min. flow bypass?
- ☐ For the total flow readings in Table 1, are the values in Condition 2 > 3 > 4?
- ☐ Collaborative Trending
 The system operation will, will not (circle) be trended to further verify the proper operation of the VFD. Points to be trended are listed in the Trending Request Form.
☐ From studying the trends, is the VFD is functioning properly?

Notes:

7. **Additional tests.** Refer to the chilled water systems sequence of operations tests for further collaboration on the VFD performance.

V. Training

___The training specified in the design incentive agreement has been completed.

VI. O&M Plan

___An acceptable O&M Plan has been put into place. Describe:

VII. Capacity Test

To insure that energy use is minimized, the hydronic system must be balanced at design conditions at the lowest possible differential pressure (DP) possible. This requires that the lowest possible DP at the sensor be found that will allow the delivery of design flow through the valve most difficult to satisfy. This system minimum DP found is what the VFD should control to. This is accomplished by changing the temperature setpoint for all zones to 55F for cooling coils or 85F for heating coils, causing all AHU coil valves to be calling for full cooling or heating, as applicable. Each coil's flow is then measured against the design flow. The coil that is receiving the lowest fraction of design is identified. The current DP at the controlling sensor is noted. A calculation is made, giving the DP required at the sensor to allow the identified most critical coil to meet its design flow. The equation is $DP_2 = DP_1 \times Q_2^2 / Q_1^2$. Where Q_1 = actual or fraction of design flow during capacity test. Q_2 = design flow or 1.0 if using fractions. DP_1 = DP at sensor. DP_2 = DP to control to. It is noted that if all coils were calling for full cooling simultaneously, the pump could not maintain the new DP_2 value, due to diversity pump size reduction having been made by the design engineer.

Parties required for VFD site commissioning work

Commissioning agent To witness and record the tests.

EMS operator To drive boxes open and shut by changing the set points, etc.

VFD technician To use the keypad to verify the ramp time. (unless verified at start-up, which is recommended). Sequencing the keypad to display ramp time could be done by the commissioning agent, alone after reviewing the VFD technical manual.

Notes:

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 16010 ELECTRICAL—GENERAL PROVISIONS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

In an appropriate section, alert Division 16 that they will be responsible for commissioning according to Section 16995, 17100 and other referenced sections.

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

END OF GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 16995 ELECTRICAL SYSTEMS COMMISSIONING

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

SECTION 16995

ELECTRICAL SYSTEMS COMMISSIONING

TABLE OF CONTENTS (with selected subheadings)

- 1.1 Description
- 1.2 Responsibilities
 - A. Electrical Contractor
 - B. Electrical Designer
- 1.3 Related Work
- 2.1 Test Equipment
- 3.1 Submittals
- 3.2 Startup
- 3.3 Functional Performance Tests
- 3.4 Testing Documentation, Non-Conformance and Approvals
- 3.5 Operation and Maintenance Manuals
- 3.6 Training of Owner Personnel
- 3.7 Deferred Testing
- 3.8 Written Work Products

PART 1 - GENERAL

1.1 DESCRIPTION

- A. The purpose of this section is to specify Division 16 responsibilities in the commissioning process which are being directed by the CA. Other electrical systems testing is required under the direction of the CM.
- B. The list of commissioned equipment and systems is found in Section 17100.1.7.
- C. Commissioning requires the participation of Division 16 to ensure that all systems are operating in a manner consistent with the Contract Documents. The general commissioning requirements and coordination are detailed in Division 17. Division 16 shall be familiar with all parts of Division 17 and the commissioning plan issued by the CA and shall execute all commissioning responsibilities assigned to them in the Contract Documents.

1.2 RESPONSIBILITIES

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

Construction and Acceptance Phases

- 1. Include the cost of commissioning in the contract price, if not yet let.
- 2. In each purchase order or subcontract written, include requirements for submittal data, O&M data and training.
- 3. Attend a commissioning scoping meeting and other necessary meetings scheduled by the CA to facilitate the Cx process.
- 4. Contractors shall provide normal cut sheets and shop drawing submittals to the CA of commissioned equipment.
- 5. Provide additional requested documentation, prior to normal O&M manual submittals, to the CA for development of start-up and functional testing procedures.
 - a. Typically this will include detailed manufacturer installation and start-up, operating, troubleshooting and maintenance procedures, full details of any owner-contracted tests, fan and pump curves, full factory testing reports, if any, and full warranty information, including all responsibilities of the Owner to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are actually shipped inside the equipment and the actual field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Commissioning Agent.
 - b. The Commissioning Agent may request further documentation necessary for the commissioning process.
 - c. This data request may be made prior to normal submittals.

The above information about special commissioning submittals is repeated in Section 01300. Maintain consistency.

6. Provide a copy of the O&M manuals submittals of commissioned equipment, through normal channels, to the CA for review and approval.
7. Contractors shall assist (along with the design engineers) in clarifying the operation and control of commissioned equipment in areas where the specifications, control drawings or equipment documentation is not sufficient for writing detailed testing procedures.
8. Provide assistance to the CA in preparation of the specific functional performance test procedures specified in Section 16997. Subs shall review test procedures to ensure feasibility, safety and equipment protection and provide necessary written alarm limits to be used during the tests.
9. Develop a full start-up and initial checkout plan using manufacturer's start-up procedures and the prefunctional checklists from the CA. Submit manufacturer's detailed start-up procedures and the full start-up plan and procedures and other requested equipment documentation to CA for review.
10. During the startup and initial checkout process, execute and document the electrical-related portions of the prefunctional checklists provided by the CA for all commissioned equipment.
11. Perform and clearly document all completed startup and system operational checkout procedures, providing a copy to the CA.
12. Address current A/E punch list items before functional testing. Air and water TAB shall be completed with discrepancies and problems remedied before functional testing of the respective air- or water-related systems.
13. Provide skilled technicians to execute starting of equipment and to execute the functional performance tests. Ensure that they are available and present during the agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments and problem-solving.
14. Perform functional performance testing under the direction of the CA for specified equipment in Section 16997 and 17100. Assist the CA in interpreting the monitoring data, as necessary.
15. Correct deficiencies (differences between specified and observed performance) as interpreted by the CA, CM and A/E and retest the equipment.
16. Prepare O&M manuals according to the Contract Documents, including clarifying and updating the original sequences of operation to as-built conditions.
17. Prepare red-line as-built drawings for all drawings and final as-builts for contractor-generated coordination drawings.
18. Provide training of the Owner's operating personnel as specified.
19. Coordinate with equipment manufacturers to determine specific requirements to maintain the validity of the warranty.

Warranty Period

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

B. Electrical Designer/Engineer

1. Refer to Section 17100 for the responsibilities of the Electrical Designer/Engineer.

1.3 RELATED WORK

- A. Refer to Section 17100, Part 1.5 for a listing of all sections where commissioning requirements are found.
- B. Refer to Section 17100 Part 1.4 for systems to be commissioned and section 17100 Part 1.6 and 16997 for functional testing requirements.

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

- A. Division 16 shall provide all test equipment necessary to fulfill the testing requirements of this Division.
- B. Refer to Section 17100 Part 2.1 for additional Division 16 requirements.

PART 3 - EXECUTION

3.1 SUBMITTALS

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

3.2 STARTUP

- A. The electrical contractors shall follow the start-up and initial checkout procedures listed in the Responsibilities list in this section and in 17100 Part 3.4. Division 16 has start-up responsibility and is required to complete systems and sub-systems so they are fully functional, meeting the design objectives of the Contract Documents. The commissioning procedures and functional testing do not relieve or lessen this responsibility or shift that responsibility partially to the commissioning agent or Owner.
- B. Functional testing is intended to begin upon completion of a system. Functional testing may proceed prior to the completion of systems, or sub-systems at the discretion of the CA and CM. Beginning system testing before full completion, does not relieve the Contractor from fully completing the system, including all prefunctional checklists as soon as possible.

3.3 FUNCTIONAL PERFORMANCE TESTS

- A. Refer to Section 17100 Part 1.4 for a list of systems to be commissioned and to Part 3.6 for a description of the process and to Section 16997 for specific details on the required functional performance tests.

3.4 TESTING DOCUMENTATION, NON-CONFORMANCE AND APPROVALS

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

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

3.5 OPERATIONS AND MAINTENANCE (O&M) MANUALS

- A. Division 16 shall compile and prepare documentation for all equipment and systems covered in Division 16 and deliver to the GC for inclusion in the O&M manuals, according to Section 01730.
- B. The CA shall receive a copy of the O&M manuals for review.

3.6. TRAINING OF OWNER PERSONNEL

- A. The GC shall be responsible for training coordination and scheduling and ultimately to ensure that training is completed. Refer to Section 17100 for additional details.
- B. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment. Refer to Section 17100 for additional details.
- C. Electrical Contractor. The electrical contractor shall have the following training responsibilities:
 - 1. Provide the CA with a training plan two weeks before the planned training according to the outline described in Section 17100, Part 3.9.
 - 2. Provide designated Owner personnel with comprehensive training in the understanding of the systems and the operation and maintenance of each major piece of commissioned electrical equipment or system.
 - 3. Training shall start with classroom sessions, if necessary, followed by hands on training on each piece of equipment, which shall illustrate the various modes of operation, including startup, shutdown, fire/smoke alarm, power failure, etc.
 - 4. During any demonstration, should the system fail to perform in accordance with the requirements of the O&M manual or sequence of operations, the system will be repaired or adjusted as necessary and the demonstration repeated.
 - 5. The appropriate trade or manufacturer's representative shall provide the instructions on each major piece of equipment. This person may be the start-up technician for the piece of equipment, the installing contractor or manufacturer's representative. Practical building operating expertise as well as in-depth knowledge of all modes of operation of the specific piece of equipment are required. More than one party may be required to execute the training.
 - 6. The training sessions shall follow the outline in the Table of Contents of the operation and maintenance manual and illustrate whenever possible the use of the O&M manuals for reference.
 - 7. Training shall include:
 - a. Use the printed installation, operation and maintenance instruction material included in the O&M manuals.
 - b. Include a review of the written O&M instructions emphasizing safe and proper operating requirements, preventative maintenance, special tools needed and spare parts inventory suggestions. The training shall include start-up, operation in all modes possible, shutdown, seasonal changeover and any emergency procedures.
 - c. Discuss relevant health and safety issues and concerns.
 - d. Discuss warranties and guarantees.
 - e. Cover common troubleshooting problems and solutions.

- f. Explain information included in the O&M manuals and the location of all plans and manuals in the facility.
 - g. Discuss any peculiarities of equipment installation or operation.
 - h. The format and training agenda in *Guidelines for Commissioning HVAC Systems*, ASHRAE, 1989R, 1996 is recommended.
 - i. Classroom sessions shall include the use of overhead projections, slides, video and audio taped material as might be appropriate.
- 8. Hands-on training shall include start-up, operation in all modes possible, including manual, shut-down and any emergency procedures and maintenance of all pieces of equipment.
 - 9. The electrical contractor shall fully explain and demonstrate the operation, function and overrides of any local packaged controls, not *controlled* by the central control system.
 - 10. Training shall occur after functional testing is complete, unless approved otherwise by the Project Manager.
 - 11. Duration of Training. The electrical contractor shall provide training on each piece of equipment according to the following schedule.

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

The Spec Writer should list and specify training for all equipment not listed here.

3.7. DEFERRED TESTING

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

3.8 WRITTEN WORK PRODUCTS

- A. Written work products of Contractors will consist of the startup and initial checkout plan described in Section 17100 and the filled out startup, initial checkout and prefunctional checklists.

END OF SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 16997 ELECTRICAL TESTING REQUIREMENTS

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet these specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

Spec Writer: A/E and design phase CA should:

1. Review the functional test requirements and add or change requirements, as necessary, for the current project. Delete requirements for equipment not existing in the current project.
2. Make sure that every piece of mechanical equipment or system has a unique test requirement or is listed as a component of a system with testing requirements given. Use the format of this section for new test requirements.
3. Include intersystem test requirements where significant interactions or interlocks exist between systems.

PART 1 - GENERAL

1.1. INCLUDED SYSTEMS AND EQUIPMENT

- A. The following is a list of the equipment and system test requirements included in this section:
1. Lighting sweep controls
 2. Daylight dimming controls
 3. Emergency power and UPS system

1.2 DESCRIPTION

- A. This section specifies the functional testing requirements for Division 15 systems and equipment. From these requirements, the Commissioning Agent (CA) shall develop step-by-step procedures to be executed by the Subs. The general functional testing process, requirements and testing methods definitions are described in Section 17100. The test requirements for each piece of equipment or system contain the following:
1. The contractors responsible to execute the tests, under the direction of the CA.
 2. A list of the integral components being tested.
 3. Prefunctional checklists associated with the components.
 4. Functions and modes to be tested.
 5. Required conditions of the test for each mode.
 6. Special procedures.
 7. Required methods of testing.

8. Required monitoring.
9. Acceptance criteria.
10. Sampling strategies allowed.

1.3 PREREQUISITES

The following applicable generic prerequisite checklist items are required to be listed on each written functional test form and be completed and checked off by CA prior to functional testing.

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

1.4 MONITORING.

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

PART 2 - PRODUCTS

— NOT APPLICABLE —

PART 3 - EXECUTION

LIGHTING SWEEP CONTROLS

- A. Parties Responsible to Execute Functional Test
1. Controls contractor: operate the controls
 2. Electrical contractor: assist in testing sequences
- B. Integral Components or Related Equipment Being Tested Prefunctional Checklist ID
PC-_____
1. Lighting Sweep Controls
- C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 16997 shall be listed on each functional test form and checked off prior to functional testing.
- D. Functions / Modes Required To Be Tested and Test Methods
The following testing requirements are an addition to and do not replace any testing requirements elsewhere in this Division.

Function / Mode	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
MISCELLANEOUS FUNCTIONS	
1. All specified functions and features are set up, debugged and fully operable.	Verbal discussion of features
2. Power failure and battery backup and power-up restart functions.	Demonstration
3. Security and access codes.	Demonstration
4. Verify override duration setting.	Demonstration
5. Scheduling features fully functional and setup, including holidays.	Observation in terminal screens or printouts
6. Date and time setting in central computer and verify that field panels read the same time.	Demonstration
SWEEP FUNCTIONS	
7. 50% of the zones with a minimum of 2 zones per controller or relay must be verified by turning on at least 25% of the lights in the zone and witnessing an actual sweep.	Either
OVERRIDE FUNCTIONS	
8. <u>Manual occupant overrides:</u> 25% of the local override switches, with a minimum of 4 switches must be verified by turning the override switches ON after a sweep and seeing the lights turn back on. 100% of the remainder of the switches should be sight verified to be in place.	Either
9. <u>Telephone and keypad overrides:</u> Test the telephone overrides by calling in for 50% of the zones. Test 50% of the keypad overrides.	Either

- E. Special Procedures (other equipment to test with, etc.; reference to function ID)
None
- F. Required Monitoring
1. None required, though monitoring can substitute for manual testing for all functions. See section 1.4 above.
- G. Acceptance Criteria (referenced by function or mode ID)
1-9 For the conditions, sequences and modes tested, the sweep controls, integral components (All) and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
- H. Sampling Strategy for Identical Units (xx% Sampling—yy% Failure Rule is defined in Section 17100, Part 3.6)
1. Sampling is as listed in the table above with a 10% Failure Rule applying.

END OF REQUIREMENTS FOR SWEEP CONTROL TEST

DAYLIGHT DIMMING CONTROLS

- A. Parties Responsible to Execute Functional Test
1. Controls contractor: operate the controls
 2. Electrical contractor: assist in testing sequences
- B. Integral Components or Related Equipment Being Tested Prefunctional Checklist ID
1. Daylight Dimming Controls PC-_____
- C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 16997 shall be listed on each functional test form and checked off prior to functional testing.
- D. Functions / Modes Required To Be Tested and Test Methods
The following testing requirements are an addition to and do not replace any testing requirements elsewhere in this Division.

<u>Function / Mode</u>	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
MISCELLANEOUS FUNCTIONS	
1. All specified functions and features are set up, debugged and fully operable.	Verbal discussion of features
2. Power failure and battery backup and power-up restart functions.	Demonstration
3. Occupant over-ride functions and duration setting.	Demonstration
4. Scheduling features fully functional and setup, including holidays.	Observation in terminal screens or printouts
5. Date and time setting in central computer.	Demonstration
DIMMING FUNCTIONS	
6. Test the sequence of operation for all features and modes.	Manual
7. Test the dimming controls during "live" conditions verifying that amperage changes in light fixtures are proportional to external light changes, and that the light levels at the specified datum points remain within specified limits. Verify this over a broad area for all areas affected. Verify that all, and only, specified light fixtures are dimming.	Either
8. Verify that delays and ramp times are set and functioning so that the speed of change of light fixture output is slow enough to be judged non-bothersome to occupants.	Manual
9. Verify that dimming does not cause lower than specified light levels in adjacent "non-dimmed" spaces.	Manual
10. Verify that the controls and sensors are not easily overridden or disabled by occupants.	Visual inspection
11. Verify that the photo sensor is in an adequate location and is not being affected by direct sunlight or obstructions.	Visual inspection

- E. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

F. Required Monitoring

1. None required, though monitoring can substitute for manual testing for most functions. See section 1.4 above.

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

- 1-11 For the conditions, sequences and modes tested, the dimming controls, integral (All) components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

H. Sampling Strategy for Identical Units (xx% Sampling—yy% Failure Rule is defined in Section 17100, Part 3.6)

1. Each photosensor and its controlled zone must be tested (no sampling).

END OF REQUIREMENTS FOR DAYLIGHT DIMMING TEST

EMERGENCY POWER AND UNINTERRUPTIBLE POWER SUPPLY SYSTEM

A. Parties Responsible to Execute or Participate in Functional Test

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

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

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

Spec Writer:

There is a wide variation in the industry as to what is sufficient testing for emergency power systems. More critical emergency power loads and generators feeding UPS systems and critical UPS loads warrant the more rigorous tests. Less critical applications will frequently omit the infrared metering and the powerline load profiler, detailed frequency and voltage stabilization tests mentioned below.

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

D. Functions / Modes Required To Be Tested and Test Methods

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

<u>Function / Mode</u>	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
Generator and ATS	
1. Document and witness startup, checkout and testing by factory representative as specified and including the following:	Demonstration
2. Safeties and alarms (including high and low oil pressure, high temperature, over-speed, derangements, etc.)	Manual
3. Sequences of operation with load bank: From a cold start, verify starting functions by recording times for engine start, ATS transfer ON, delay to OFF, engine cool down, etc.	Either
4. Load bank generator to 100% for 1 hour. Record every 5 min.: volts & amps (each phase), frequency, using load profiler, engineer coolant temp. and oil pressure.	Combination

Function / Mode	<u>Test Method</u> Manual (demonstration), Monitoring, Either or Both
5. Voltage and frequency regulation over various loads. Verify that frequency and voltage is within specified ranges at steady state and step loads of 0%-50%, 0%-100%, 100%-50% and 50%-100% in that order using a power line load profiler. Verify that frequency stability (rate of change) is adequate.	Combination
6. Using actual building emergency loads, tune the generator output frequency and voltage for use by the UPS, using a load profiler or oscilloscope. (This could be done during the Integrated Building Test).	Combination
7. Verify annunciations to BAS and remote monitoring sites.	Monitoring
8. During the above tests use an infrared meter on the ATS contacts and look for hot spots and significant variations between contracts.	Manual
9. Monitor and instrument as required to make positive observations of test results.	Either
10. Operation during Integrated Test.	Manual
UPS	
11. By actual power outage, verify sequence of operation of UPS. Use actual UPS loads if possible, else use load bank: at what voltage UPS starts, time to transfer back to E-power, etc. Verify proper frequency window and slew rate with powerline analyzer. Tune UPS and generator governor as necessary. Partially drain batteries and verify charging sequences.	Manual
12. Simulate all alarms critical malfunctions and verify annunciations and protective device functioning.	Manual
13. Verify annunciations to BAS and remote monitoring sites.	Monitoring
14. During the above tests use an infrared meter on the UPS contacts and look for hot spots and significant variations between contracts.	Manual
15. Monitor and instrument as required to make positive observations of test results.	Either
16. Operation during Integrated Test.	Manual
Integrated Building Test	
17. The emergency power and UPS system and all integral components will be tested together through actual power outages with as much emergency loads operating as possible. Physical verification of emergency power to all emergency powered systems and equipment, including lighting, HVAC, telecommunications, fire alarm, elevator (test actual recall function), security, lighting and the controls system shall be documented. Communication responses to remote monitoring reception points, the local building automation system and visual points within the building will be documented. Critical voltage sensing, timing, delays, voltages, amperages and groundings will be documented.	Manual

E. Special Procedures (other equipment to test with, etc.; reference to function ID)
None, except as noted.

F. Required Monitoring

1. See Requirements 4, 5, 8. See Section 1.4 above.

- G. Acceptance Criteria (referenced by function or mode ID)
1-17 For the conditions, sequences and modes tested, the emergency power and UPS system,
(All) integral components and related equipment respond to changing conditions and parameters
appropriately as expected, as specified and according to acceptable operating practice.
- H. Sampling Strategy for Identical Units (xx% Sampling—yy% Failure Rule is defined in Section
17100, Part 3.6)
1. None. Test all.

END OF REQUIREMENTS FOR EMERGENCY POWER SYSTEM TEST

END OF THIS GUIDE SPECIFICATION SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 16998 PREFUNCTIONAL CHECKLISTS

ELECTRICAL

Spec writer:

The following guide specifications are intended to be reviewed, modified and inserted into the noted specification section to meet the specific commissioning needs and requirements for the current project. Any modifications to these specifications shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

SECTION 16998

PREFUNCTIONAL CHECKLISTS

ELECTRICAL

A. GENERAL

All prefunctional checklists for both mechanical and electrical are found in Section 15998.

END OF SECTION

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 16999

SAMPLE FUNCTIONAL TEST PROCEDURES

ELECTRICAL

Spec writer:

The following example functional test procedures are provided for reference and do not necessarily reflect equipment or conditions in this project. The commissioning agent will write specific functional test procedures for this project.

SECTION 16999

SAMPLE FUNCTIONAL TEST PROCEDURES

ELECTRICAL

A. GENERAL

This section contains sample Functional performance Test procedures in a form format (FT).

The sample FT procedures displayed in a form format here are intended to provide the Subs and CA with an example of a format and an indication of the rigor of the required testing and documentation for various equipment types. They were not developed for this project. Other forms and formats are acceptable if they comply with the rigor, clarity and intent of all the commissioning specifications. The CA will use the functional testing requirements in Sections 15997 and 16997 and the testing protocols specified in Section 17100 for developing site-specific functional test procedures and forms for this project. For illustrative purposes, sequences of operation associated with a few pieces of the equipment for which tests are included are also provided.

B. SAMPLE FUNCTIONAL TESTS (Examples only, not for this project)

This guide specifications section continues with functional tests for the following equipment. The tests are provided in electronic file format (Word 6.0 for Windows 3.1). The file name is at the bottom of each page. The file name extension “ft__” stands for Functional Test and the last digit is the version number. Any MS Excel spreadsheet files are noted with their usual .xls extension. Some of the equipment also has a file with its full sequences of operation, for reference when viewing the test procedures, and to illustrate the desired rigor of sequences of operation.

Additional example functional tests for mechanical equipment are found in Section 15999.

SYSTEM

ELECTRONIC FILE NAME

Emergency power and UPS (comprehensive, big)	e-powbig.ft_
Emergency power and UPS	e-power.ft_
Exterior lighting controls	extlight.ft_
Lighting sweep controls	sweep.ft_

C. SUGGESTED NUMBERING KEY FOR COMMISSIONING PROCEDURES

The checklists, functional tests, documentation and training use the following identification numbering:

At the beginning of the identification number is a text abbreviation for the following:

Document or Event Abbreviations

DOC = Documentation
PC = Prefunctional Checklist
SP = Start-up Plan
SR = Start-up Report
FT = Functional Test
R = Review
TR = Training Record

Numbering Key

FT-0102.3: The first four digits uniquely identify the piece of equipment to the component level. The first 2 digits are the System Type, the second 2 digits are an arbitrary component number (not necessarily the same as the specified ID number). The number after the decimal is the test number. For example, FT-0102.3 = Functional Test 3 of system Type 1, component number 2 (e.g., 0102.3 = Chiller #2, FT #3, because chillers are System Type 1). Other components under chillers are: additional chillers, pumps, valves, piping, VFDs. The component number of 00 means "general" or "all" components, as with the entire system. All tests, procedures, trainings and records should have the same first 4 digits for any given equipment component.

Another example is TUs. If there were only 1 TU type, then tests would be numbered FT-0500.1, 0500.2, etc. If there were 2 types of TUs: FT-0501.1, 0501.2, etc. and 0502.1, 0502.2, etc.

An example of the number system follows:

<p>0100 Chilled Water System</p> <p>0101 Chiller 1</p> <p>0102 Chiller 2</p> <p>0103 Cooling tower 1</p> <p>0104 Cooling tower 2</p> <p>0105 Pump CHWP-1</p> <p>0106 Pump CHWP-2</p> <p>0107 CHW piping</p> <p>0108 CDW piping</p> <p>0109 Sensor calibration</p>	<p>0200 Boiler System</p> <p>0201 Boiler 1</p> <p>0202 Boiler 2</p> <p>0203 Pump HWP-1</p> <p>0204 Pump HWP-2</p> <p>0205 HW piping</p> <p>0206 Sensor calibration</p> <p>etc.</p>
---	--

Numbers for Primary System Types and Components

Components are in parentheses.

- 01 Chilled water system (chillers, cooling towers, pumps, condensers, piping, valves)
- 02 Hot water system (boilers, hot water pumps, valves, piping)
- 03 Air handler units (SF, RF, coils, valves, VFD, ducts, dampers)
- 04 Packaged, AC or HP units (SF, RF, coils, valves, VFD, ducts, dampers, compressors, condensers)
- 05 Terminal units
- 06 Computer room AC units
- 07 Unit heaters or AC spot coolers
- 08 Heat exchangers
- 09 Service water system
- 10 Test and balance (TAB)
- 11 Building automation system (controls)
- 12 Lighting controls
- 13 Specialty fans
- 14 Fume hoods

END OF SECTION

Functional Test

Project _____

FT-_____ EMERGENCY POWER SYSTEM

(Short Test Version, less rigorous UPS test)

Including Emergency Generator, ATS and UPS

Related Tests: _____

1. Participants

Party

Participation

_____	_____
_____	_____
_____	_____

Party filling out this form and witnessing testing _____

Dates of tests _____

2. Test Prerequisites

- a. ☐ The following have been started up and startup reports and prefunctional checklists submitted and approved ready for functional testing:
 - ☐ Emergency generator and ATS
 - ☐ UPS
- b. ☐ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules and with debugging, loop tuning and sensor and device calibrations completed.

_____ Controls Contractor Signature or Verbal

_____ Date
- g. ☐ All A/E punchlist items for this equipment corrected.
- h. ☐ These functional test procedures reviewed and approved by installing contractor and vendors.
- i. ☐ Safeties and operating ranges reviewed.
- j. ☐ Test requirements and sequences of operation attached.
- o. ☐ Verify that generator gages and meters for voltage, amperage and frequency are calibrated to hand-held or load profiler instrument readings.
- p. ☐ Other misc. checks of the prefunctional checklist and startup reports completed successfully.
- q. ☐ Monitoring security company notified of test. Arrangements made to test UPS loads (or load bank).

Notes:

3. Testing Procedures and Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
Initial Procedures					
A		The contractor shall follow the following acceptance procedure with the engine cold and no connected load. With ATS switch in the manual position, open the ATS breaker. Restore ATS to automatic position and close ATS breaker.	Verify that power has been lost from each load served by emergency power.		
B		Connect Power Line Disturbance Monitor (PDM), Load Profiler and recording Multimeter to UPS and Backup Generator/ATS.			
Generator, ATS and Loads					
1		Cold Start. Open normal power breakers and immediately connect <u>full</u> load bank load capacity to ATS units. This connection must be made before engine generator is up to speed and transfer to E-power has been completed.	Observe the system's performance and record the following data using a Power Line Disturbance Monitor to monitor the transient responses. Compare to specifications.		
2		Measure time using PDM.	Time delay from power failure to engine start signal should be within _____ sec., [_____ sec].		
3		Measure time using PDM.	Cranking time until prime-mover starts and runs should be within _____ sec., [_____ sec.].		
4		Measure time using PDM.	Time until engine-generator is at proper voltage and frequency should be within _____ sec. [_____ sec].		
5		Measure time using PDM.	Total time from power failure until ATS switch is on E-power should be within _____ sec., [_____ sec].		
6		OPTIONAL: Repeat procedures 1-5.	Document variances from specified performance.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
7		Full Load Test. Continue generator operation. Record voltage and amperage of each phase and frequency using a load profile monitor, not generator gages; engine coolant temperature, oil pressure, and battery charge rate at 5 minute intervals for a period of one hour. OPTIONAL: Measure the temperature of all generator and ATS connections using a laser guided infrared temperature meter, Raytech or approved.			

Performance Criteria for Data in Table Below (by Column number).

1) 5 minute intervals	7) Batt. Charge: _____
2) Volts: _____	8) Ambient temperature: none
3) Hertz: _____	9) ATS Contacts Input Temp.: Note any significant
variances between phases.
4) Amps: _____	10) ATS Contacts Output Temp.: Note any significant
variances between phases
5) Coolant T: _____	
6) Oil pressure: _____	

1	2	3	4	5	6	7	8	9	10	11
Time	Volts	Amps	Hertz	Engine Coolant Temp.	Oil Press	Batt. Charge	Temp. @ Gen.	Temp.@ ATS Input (list ea. phase)	Temp.@ ATS Output (list ea. phase)	Note Number

Notes:

1	2	3	4	5	6	7	8	9	10	11
Time	Volts	Amps	Hertz	Engine Coolant Temp.	Oil Press	Batt. Charge	Temp. @ Gen.	Temp.@ ATS Input (list ea. phase)	Temp.@ ATS Output (list ea. phase)	Note Number

Test Procedures Continued:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
8		Disconnect load bank load from ATS, before transfer back to normal power. Restore normal power and record delay to normal power transfer.	Delay to normal power should be _____min., [_____min.].		
9		Record neutral delay time (if applicable) or verify in-phase monitor is working by recording voltage differential between Engine Generator Power and Utility Power at the time of the transfer back to normal power.	Neutral delay time should be _____sec., [_____sec.].		
10		Record engine cool-down time. (Engine continues to run after ATS transfer.)	Cool down time should be _____min., [_____min.].		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #																														
11		<p>Step Load Tests.</p> <p>After the cool-down timer has expired, start the engine-generator by opening the ATS normal input power circuit breaker. With the emergency bus energized, perform the adjacent step load tests, verifying that voltage and frequency remain within specified ranges during transition and that the frequency stability (rate of change) is acceptable. Observe and record frequency and voltage response using the Powerline Disturbance Monitor.</p> <p>Tune generator governor output to meet adjacent specifications. Document.</p>	<p>Specified frequency regulation range = +/- _____ Hz</p> <p>Specified voltage regulation range = +/- _____ V</p> <p>Specified frequency stability criteria: _____.</p> <p>Max. variance of:</p> <table><tr><th>Step</th><th>Volt.</th><th>Freq.</th><th>Stabil.</th><th>OK</th></tr><tr><td>0-25%</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr><tr><td>0-50%</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr><tr><td>0-100%</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr><tr><td>100-50%</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr><tr><td>100-25%</td><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr></table> <p>Governor tuned to meet specs.</p>	Step	Volt.	Freq.	Stabil.	OK	0-25%	_____	_____	_____	_____	0-50%	_____	_____	_____	_____	0-100%	_____	_____	_____	_____	100-50%	_____	_____	_____	_____	100-25%	_____	_____	_____	_____		
Step	Volt.	Freq.	Stabil.	OK																															
0-25%	_____	_____	_____	_____																															
0-50%	_____	_____	_____	_____																															
0-100%	_____	_____	_____	_____																															
100-50%	_____	_____	_____	_____																															
100-25%	_____	_____	_____	_____																															
12		<p>OPTIONAL: Connect full load bank load to ATS. Maintain power flow for 15 minutes, then take temperature readings with infrared meter looking for hot spots.</p>	<p>There should be no significant variations in temperature between phases.</p> <table><tr><th>Point</th><th>T1</th><th>T2</th><th>T3</th></tr><tr><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr></table>	Point	T1	T2	T3	_____	_____	_____	_____																								
Point	T1	T2	T3																																
_____	_____	_____	_____																																
13		<p>OPTIONAL: Transfer load back to utility source. Maintain power flow for 15 minutes and take temperature readings with infrared meter looking for hot spots.</p>	<p>There should be no significant variations in temperature between phases.</p> <table><tr><th>Point</th><th>T1</th><th>T2</th><th>T3</th></tr><tr><td>_____</td><td>_____</td><td>_____</td><td>_____</td></tr></table>	Point	T1	T2	T3	_____	_____	_____	_____																								
Point	T1	T2	T3																																
_____	_____	_____	_____																																
14		<p>ATS TEST SWITCH. Operate the ATS test switch and verify that the generator starts and the E-Power sequence is initiated. (Bypass the return to normal timer to accelerate the test sequence.)</p>	<p>Generator should start and E-power sequence initiated.</p> <p>Verify that total time to E-power meets that specified (see Procedure 5).</p>																																
15		<p>OPTIONAL: Safety interlocking will be demonstrated by trying to operate the ATS and controls in a deranged manner, if possible.</p>	<p>Alarms should be generated and E-power system go or remain off-line.</p>																																

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
16		a) Simulate all alarms, alarm contact operation and remote enunciator operation by jumping across alarm contacts at ATS and generator. b) Verify any alarms to the BAS or other remote monitoring sites.	a) All alarms are properly annunciated in the remote panel. b) Alarms received by BAS and remote sites.		
17		Check calibration of ATS digital readouts of frequency, current and volts against a calibrated instrument.	ATS values should be within the following tolerances: Hz: _____ [_____] Amps: _____ [_____] Volts: _____ [_____]		
UPS and Integrated Building Test					
18		Prepare to operate all facility loads connected to the backup power system, including UPS loads. Connect load profiler to generator system. Begin operating as many of the emergency loads as possible (both UPS and other). (If UPS loads cannot be tested live, install a full load bank on the UPS.) With ATS, generator and UPS in normal auto mode, cut power to emergency loads. Do not load bank generator.	Observe the generator start and ATS switch to generator power.		
19		With the generator providing power for actual building loads, tune generator governor output to meet adjacent specifications and for optimal compatibility with UPS. Document results..	Specified frequency regulation range = +/- _____ Hz Specified voltage regulation range = +/- _____ V Specified frequency stability criteria: _____ Final max. variance during building test: <div style="display: flex; justify-content: space-around; margin-top: 5px;"> <u>Volt.</u> <u>Freq.</u> <u>Stabil. OK</u> </div> <div style="display: flex; justify-content: space-around; margin-top: 5px;"> _____ _____ _____ </div> <div style="display: flex; justify-content: space-around; margin-top: 5px;"> _____ _____ _____ </div> Governor tuned to meet specs.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
20		UPS Connect load profiler to UPS and monitor the UPS load voltage, frequency and amperage with load profiler, through transition (dynamic) and at steady state.	Verify UPS goes back to generator power (off battery and stays off), per spec. Verify that specified voltage dynamic regulation is met: Dynamic voltage overshoot should be within _____; Actual: _____. Steady-state voltage variation should be within +/- _____; Actual: _____. Frequency overshoot should be within _____; Actual: _____. THD should be less than 5%. Wave form deviation should be minimal.		
20a		Measure the amperage of each phase off the UPS. Verify that they are balanced.	Phase A = [_____] Phase B = [_____] Phase C = [_____] Phase imbalance is within ____%?		
21		Tune UPS opening and closing of frequency window and slew rate.	UPS tuned.		
22		Simulate all alarms, alarm contact operation and remote enunciator operation by jumping across alarms. List.	All alarms are properly annunciated.		
23		Change ATS to manual and cut emergency power to UPS. Monitor UPS. Allow batteries to drain 25% or more.	Observe that loaded UPS provides sufficient power.		
24		Restore emergency power to UPS.	Verify that UPS is charging properly from the generator.		
25		Verify function of UPS bypasses.	Bypasses function per spec.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
31a		a. Security panel. Verify that it is functioning by heating the Security Co. stat in the Telecom room above its alarm setpoint (____80F) and having Security Co. fax the printout of the trouble report.	OK?		
31b		b. Fire alarm panel. Verify that it is functioning by initiating an alarm and then resetting.	OK?		
31c		c. Med-gas alarm. Derange the system and verify that an alarm was initiated.	OK?		
31d		d. Dental chairs in rms. _____. Verify power to their outlets or try some functions.	OK?		
31e		e. <u>Telecom HVAC</u> . Using a heat gun, increase the temperature at the FCU-2 stat 5F above its setpoint (____77F). Observe FCU-2 and ACU-1 start and deliver cool air to the room. Remove heat and observe units cycle OFF.	OK?		
31f		f. <u>Telecom System</u> . Verify that telecom loads are functioning properly under emergency power (unless UPS had to be load banked).	OK?		
31g		g. <u>Elevator</u> . Test the elevator recall function under emergency power.	Elevator recalls per specified sequences.		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
32		<p><u>UPS Monitored Alarms.</u> The following alarms are monitored by the Security Co. Verify their function by causing the alarm, recording the time and having Security Co. fax a copy of the alarm report.</p> <p>a) Electrical failure. Simulate an electrical failure or malfunction.</p> <p>b) Detection of power being switched to the UPS. Verify during one of the previous transfers.</p> <p>c) Low Battery. Simulate a low battery condition.</p> <p>d) Space temperature above alarm setpoint. Heat stat above setpoint.</p>	OK?		

Notes:

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N	Note #
33		As necessary, provide any attachments and a written report beyond this test form comparing measurement data with factory and project specifications, in areas that do not comply or where additional documentation or explanation is necessary.			
34	—	Return all changed control parameters and conditions to their pre-test values ⁵			

¹Sequences of operation attached to this test.

²Mode or function ID being tested from testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition. Fill-in spaces or lines not in brackets denote sequence parameters still to be specified by the A/E, controls contractor or vendor. Write "Via BAS" for verifications of device position from BAS readout or "Via obs" for actual observation or from test instrument reading.

⁵Record any permanently changed parameter values and submit changes to Owner.

A SUMMARY OF DEFICIENCIES IDENTIFIED DURING TESTING IS ATTACHED

— END OF TEST —

Notes:

Functional Test

Project: _____

FT-_____ EXTERIOR LIGHTING CONTROLS

1. Participants

Party

Participation

Party filling out this form and witnessing testing _____
 Date of test _____

2. Prerequisite Checklist

- a. ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints, schedules, debugging and fine tuning of photo-cell parameters.

 Controls Contractor Signature or Verbal

 Date

- b. ___ All A/E punchlist items for this equipment corrected.
 c. ___ Safeties and operating ranges reviewed.
 d. ___ Test requirements and sequences of operation attached.
 e. ___ Schedules and setpoints attached.
 f. ___ Have all energy savings control strategies, setpoints and schedules been incorporated that this equipment and control system are capable of? If not, list recommendations below.
 g. ___ **BAS Program Review.** Review the BAS software control program(s) for this equipment. Parameters, setpoints and logic sequences appear to follow the specified written sequences.
 h. ___ Schedule of fixtures on each control type (Parking or Security) has been reviewed.
 i. ___ Record of All Values for Current Setpoints (SP), Control Parameters, Limits, Delays, Lockouts, Schedules, Etc. Changed to Accommodate Testing:

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
Parking lot lights schedule	<u>ON</u> by photo cell <u>OFF</u> by sched:	
Photo-cell BAS parameters		

Parameter	Pre-Test Values	Returned to Pre-Test Values ✓
Exterior security lights schedule	<u>ON</u> by photo cell <u>OFF</u> by photo-cell	

Notes:

3. Sensor Calibration Checks. Check the sensors listed below for calibration and adequate location. This is a sampling check of calibrations done during prefunctional checklisting. Test the packaged controls and BAS readings.
--NONE--

4. Device Calibration Checks.
--NONE--

5. Verification of Misc. Prefunctional Checks.

Misc. site checks of the prefunctional checklist and startup reports completed successfully. Pass? Y / N _____
 ___ Photo-cell (PC) mounted securely. ___ PC mounted where it won't be tampered with. ___ PC mounted so it won't become dirty easily. ___ PC accessible for servicing.

6. Functional Testing Record

Proced. No. & Spec. Seq. ID ¹	Req ID No. ²	Test Procedure ³ (Including special conditions)	Expected and Actual Response ⁴ [Write ACTUAL response in brackets or circle]	Pass Y/N & Note #
1		Near dusk, observe exterior lights until they come ON. (Witnessed by Owner's Rep: _____)	All exterior lights come on at dusk, before dark, but not when still very light.	
2		a) Change the Parking Lot light schedule OFF to be in 5 minutes. b) Return schedule to normal.	a) Observe that the parking lot lights, designated by the approved schedule, shut OFF. Designated signage remains ON. b) Schedule returned to normal.	
3		Before daylight in the morning, observe the security lights ON. Wait until dawn. (Witnessed by Owner's Rep: _____)	When sufficiently light, Security Lights and signage lights shut OFF.	
4	—	Return all changed control parameters and conditions to their pre-test values ⁵	Check off in Section 2 above when completed	

Record Foot Notes

¹Sequences of operation specified in Contract Documents (attached).

²Mode or function ID being tested, per testing requirements section of the project Specifications.

³Step-by-step procedures for manual testing, trend logging or data-logger monitoring.

⁴Include tolerances for a passing condition.

⁵Record any permanently changed parameter values and submit to Owner.

— END OF TEST —

Notes:

Functional Performance Test

Lighting Sweep

Project _____ Date _____

Commissioning _____

Operator executing sweeps _____ of _____

1. **Sweep Controller Type:** _____ part of EMS, _____ separate PC system, _____ stand-alone controllers (give quantity), _____ stand-alone integrated into EMS.

Brand and model: _____

Type of system: _____ Sweeps off lights until morning. Override timers allow zones to be turned back on.

_____ Sweeps off lights. Any light can than be turned back on by a:
_____ standard switch, _____ phone call within building

2. **Documentation.** Verify that full documentation of the controller is *permanently* on site and includes the following:

_____ specifications and features

_____ list of loads and zones each relay controls attached*

_____ contact number for additional assistance attached*

_____ current written list of sweep schedules for all zones attached*

_____ programming instructions attached*

_____ controller warranty (in submittals)

_____ written instructions for tenants in using the local overrides and a description of the areas they control

*Attached = attached to the controller panel door or if PC computer controlled, in documentation manual

3. **Training.** If there is a full-time building operator in the building or building complex, they must be trained to fully understand the programming of the sweep controls, the operation of the total override and of the local overrides and have access to the system's full documentation.

Full-time operator? _____ Yes _____ No

If Yes, installing contractor performing training _____.

If Yes, individual trained as the "operator" _____.

Review and approve the written instructions distributed to the tenants regarding the operation of the local overrides. Approved and distributed: _____ Yes _____ No

4. **Verification of capabilities and performance.** Verify that the controller has the following features and capabilities: (check-mark denotes acceptance)

_____ 4.1. Programming capabilities via keypad or EMS interface. Verify by running through the current program and schedules.

_____ 4.2. Back-up power supply (automatically recharged) that will retain program for _____ weeks without power. Verify by viewing specifications and battery pack.

_____ 4.3. Lockable controller enclosure or room with key or code-only access for programming and total override or access is in a restricted PC program.

_____ 4.4. The controlling time clock is reading the appropriate time.

___ 4.5. Override duration *set* to not more than 2 hours

___ 4.6. Each override as tested below, energizes no more than 5000 sf of floor area.

4.7. Verify actual sweep and override operation of each controller as per table below.

Sweep Operation Verification

Day Type and Sweep No.	Schedule of Sweeps (hour of day)				
	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
	ID:	ID:	ID:	ID:	ID:
	Relay ID:	Relay ID:	Relay ID:	Relay ID:	Relay ID:
Weekdays 1					
(enter schedules 2					
in these rows) 3					
Saturday 1					
2					
Sunday 1					
2					
Fixtures/rooms excluded from sweep					
Sweep verification type¹					
No. of local override switches (actual / spec'd)					
No. of override switches tested²					

Test Procedures

¹ **Sweeps.** 50% of the zones with a minimum of 2 zones per controller or relay must be verified by turning on at least 25% of the lights in the zone and witnessing an actual sweep. The remainder of the zones must have the programming of their schedules verified.

In the table above, enter all of the following codes that apply:

0 = not verified, S = verified Schedule in keypad or EMS display, W = verified operation by Witnessing a sweeping off of the lights at a special scheduled time, F = witnessed sweep, but sweep Failed to function properly. Refer to comments.

² **Overrides.** 25% of the local override switches with a minimum of 4 overrides must be verified by turning the override switches on after a sweep and seeing the lights turn back on. 100% of the remainder of the switches should be sight verified to be in place. For each Zone, enter the number of override switches where functionality was actually witnessed. Verify that the local override only controls the specified zone.

Comments:

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 17100 COMMISSIONING REQUIREMENTS

Spec writer:

The following guide specifications are intended to be reviewed and modified to meet the specific commissioning needs and requirements for the current project and systems. Any modifications to this specification shall only be made after consultation with the Owner's representative and with approval of the engineer of record. Where there are check boxes or fill-in blanks, fill in as appropriate and delete all but the choice(s) that apply. Delete all direction boxes.

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PART 1 - GENERAL

1.1 DESCRIPTION

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

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

- 1) Verify that applicable equipment and systems are installed according to the manufacturer's recommendations and to industry accepted minimum standards and that they receive adequate operational checkout by installing contractors.
 - 2) Verify and document proper performance of equipment and systems.
 - 3) Verify that O&M documentation left on site is complete.
 - 4) Verify that the Owner's operating personnel are adequately trained.
- B. The commissioning process does not take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product.
- C. Abbreviations. The following are common abbreviations used in the *Specifications* and in the *Commissioning Plan*. Definitions are found in Section 1.6.

A/E-	Architect and design engineers	FT-	Functional performance test
CA-	Commissioning agent	GC-	General contractor (prime)
CC	Controls contractor	MC-	Mechanical contractor
CM-	Construction Manager (GSA's representative)	PC-	Prefunctional checklist
Cx-	Commissioning	PM-	Project manager (of GSA)
Cx Plan-	Commissioning Plan document	Subs-	Subcontractors to General
EC-	Electrical contractor	TAB-	Test and balance contractor

1.2 COORDINATION

- A. Commissioning Team. The members of the commissioning team consist of the Commissioning Agent (CA), the GSA Project Manager (PM), the designated representative of the owner's (GSA) Construction Management firm (CM), the General Contractor (GC or Contractor), the architect and design engineers (particularly the mechanical engineer), the Mechanical Contractor (MC), the Electrical Contractor (EC), the TAB representative, the Controls Contractor (CC), any other installing subcontractors or suppliers of equipment. If known, the Owner's building or plant operator/engineer is also a member of the commissioning team.
- B. Management. The CA is hired by the ___CM, ___GC, ___A/E, ___GSA directly. The CA directs and coordinates the commissioning activities and the reports to the ___CM, ___is part of the CM team. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents. The CA's responsibilities are the same regardless of who hired the CA. Refer to Section 17100 Part 1.6 for additional management details. The following organization chart clarifies the roles.

The following organization charts may assist in making it clear how the CA fits into the management plan for this project. Use or modify one of these in the Specifications and delete the others.

CA Hired by the GC, Reporting to the CM

CA Hired by the A/E, Reporting to the CM

CA Hired by the CM, or Directly by GSA

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

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

1.3 COMMISSIONING PROCESS

Spec writer:

If no commissioning plan was issued at bidding, delete the first sentence of the following paragraph

- A. Commissioning Plan. The *Commissioning Plan*, Draft 2, provided as part of the bid documents, is binding on the Contractor. The commissioning plan provides guidance in the execution of the commissioning process. Just after the initial commissioning scoping meeting the CA will update the plan which is then considered the “final” plan, though it will continue to evolve and expand as the project progresses. The *Specifications* will take precedence over the *Commissioning Plan*.
- 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 scoping 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, 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 Subs in developing startup plans and startup documentation formats, including providing the Subs with prefunctional checklists to be completed, during the startup process.
 5. In general, the checkout and performance verification proceeds from simple to complex; from component level to equipment to systems and intersystem levels with prefunctional checklists being completed before functional testing.
 6. The Subs, under their own direction, 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 may include the CA witnessing start-up of selected equipment.
 7. The CA develops specific equipment and system functional performance test procedures. The Subs review the procedures.
 8. The procedures are executed by the Subs, under the direction of, and documented by the CA.
 9. Items of non-compliance in material, installation or setup are corrected at the Sub’s expense and the system retested.
 10. The CA reviews the O&M documentation for completeness.
 11. Commissioning is completed before Substantial Completion.
 12. The CA reviews, pre-approves and coordinates the training provided by the Subs and verifies that it was completed.
 13. Deferred testing is conducted, as specified or required.

1.4 RELATED WORK

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

00800 Supplementary Conditions Provides for a penalty if commissioning is not completed by the Functional Completion milestone.

* If the commissioning agent is hired by the owner or construction manager, 01040a applies:

01040a Coordination Introduces commissioning and refers to Division 17.

* If the commissioning agent is hired by the general contractor, 01040b applies:

01040b Coordination	Introduces commissioning, refers to Division 17 and requires that the GC hire a qualified CA.
01300 Submittals	Alerts all parties that additional detail in submittals may be required and directs to Division 17.
01700 Project Close-out	Defines Substantial Completion and Functional Completion milestones, relative to commissioning.
01730 O&M Data	Alerts all parties that O&M documentation may be more detailed and directs to Division 17.
15010 Mechanical General	Alerts the mechanical contractor to Cx responsibilities in 15995.
15950 Automatic Controls	Lists special requirements and alerts the controls contractor of the special requirements of the control contractor and control system in 15995.
15990 TAB	Alerts the TAB of Cx responsibilities in 15995.
15995 Mechanical Cx	Describes the Cx responsibilities of the mechanical, controls and TAB contractors and the prefunctional testing and startup responsibilities of each. Points to 15997 for functional testing requirements.
15997 Mechanical Testing Requirements	Describes the specific functional testing requirements for Division 15 equipment in the project.
15998 Mechanical Prefunctional Checklists	Provides the prefunctional checklists for use on this project, including items for Div. 15 <i>and</i> Div. 16.
15999 Mechanical Functional Tests—Examples	Provides example functional test procedures and formats for mechanical equipment.
16010 Electrical General	Alerts the electrical contractor of Cx responsibilities in 16995.
16995 Electrical Cx	Describes the Cx responsibilities of the electrical contractor.
16997 Electrical Testing	Describes the specific functional testing requirements Requirements for Division 16 equipment in the project.
16998 Electrical Prefunctional Checklists	Points to Section 15998.

16999 Electrical Functional
Tests-Examples

Provides example functional test procedures
and formats for electrical equipment.

17100 Commissioning

Describes the commissioning process, responsibilities common to all parties, responsibilities of the A/E, CA, CM, PM, GC and Suppliers, focusing on the CA. The unique MC, CC, TAB and EC responsibilities are included in Div. 15 and 16.

Spec Writer: List other sections or divisions that have systems commissioned. Include alerts in Section 10 of the division, division commissioning responsibilities in section 995 of the division, and actual test requirements in section 997, all similar to Division 15.

1.5 RESPONSIBILITIES

- A. The responsibilities of various parties in the commissioning process are provided in this section. The responsibilities of the mechanical contractor, TAB and controls contractor are in Division 15 and those of the electrical contractor in Division 16 and those of [list other sections where requirements of other divisions are found]. It is noted that the services for the GSA 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.

If the CA is hired by the GC or A/E, delete "Commissioning Agent" in the above paragraph.

Spec writer should make sure that language in the contract and general conditions states that the contractors are paying for their part in the commissioning and testing; the Owner is not paying as an extra.

Spec writer:

If no commissioning plan was issued at bidding, delete item number 1 under B, "Follow the Commissioning Plan."

B. All Parties

1. Follow the Commissioning Plan.
2. Attend commissioning scoping meeting and additional meetings, as necessary.

C. Architect (of A/E)

Construction and Acceptance Phase

1. Manage the CA contract, GC manages the CA contract, CM or GSA manages the CA contract.

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

Warranty Period

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

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

Construction and Acceptance Phase

1. Perform normal submittal review, construction observation, as-built drawing preparation, etc., as contracted. One site observation should be completed just prior to system startup.
2. Provide any design narrative and sequences documentation requested by the 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.
3. Attend commissioning scoping meetings and other selected commissioning team meetings.
4. Participate in the resolution of system deficiencies identified during commissioning, according to the contract documents.
5. Prepare and submit the final as-built design intent and operating parameters documentation for inclusion in the O&M manuals. Review and approve the O&M manuals.
6. Provide a presentation at the first training session for the Owner's personnel.

OPTIONAL:

7. ☐ Review, ☐ Approve the prefunctional checklists for major pieces of equipment for sufficiency prior to their use.
8. ☐ Review, ☐ Approve the functional test procedure forms for major pieces of equipment for sufficiency prior to their use.
9. ☐ Witness testing of selected pieces of equipment and systems: _____

Warranty Period

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

Spec writer:

If no commissioning plan was issued at bidding, modify as appropriate, any references to the commissioning plan throughout the rest of this section.

E. Commissioning Agent (CA)

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 or deficiencies, but ultimately that responsibility resides with the general contractor 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—that systems are functioning in accordance with the documented design intent and in accordance with the Contract Documents. The Contractors will provide all tools or the use of tools to start, check-out and functionally test equipment and systems, except for specified testing with portable data-loggers, which shall be supplied and installed by the CA.

Construction and Acceptance Phase

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

- management control system trending, stand-alone datalogger monitoring or manual functional testing. Submit to CM for review, and for approval if required.
19. Analyze any functional performance trend logs and monitoring data to verify performance.
 20. Coordinate, witness and approve manual functional performance tests performed by installing contractors. Coordinate retesting as necessary until satisfactory performance is achieved.
 21. Maintain a master deficiency and resolution log and a separate testing record. Provide the CM with written progress reports and test results with recommended actions.
 22. Witness performance testing of smoke control systems by others and all other owner contracted tests or tests by manufacturer's personnel over which the CA may not have direct control. Document these tests and include this documentation in Commissioning Record in O&M manuals.
 23. Review equipment warranties to ensure that the Owner's responsibilities are clearly defined.
 24. Oversee and approve the training of the Owner's operating personnel.
 25. Compile and maintain a commissioning record and building systems book(s).
 26. Review and approve the preparation of the O&M manuals.
 27. Provide a final commissioning report.

Warranty Period

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

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

Construction and Acceptance Phase

1. Facilitate the coordination of the commissioning work by the CA, and, with the GC and CA, ensure that commissioning activities are being scheduled into the master schedule.
2. Review and approve the final *Commissioning Plan—Construction Phase*.
3. Attend a commissioning scoping meeting and other commissioning team meetings.
4. Perform the normal review of Contractor submittals.
5. Furnish a copy of all construction documents, addenda, change orders and approved submittals and shop drawings related to commissioned equipment to the CA.
6. Review and approve the functional performance test procedures submitted by the CA, prior to testing.
7. When necessary, observe and witness prefunctional checklists, startup and functional testing of selected equipment.
8. Review commissioning progress and deficiency reports.
9. Coordinate the resolution of non-compliance and design deficiencies identified in all phases of commissioning.
10. Sign-off (final approval) on individual commissioning tests as completed and passing. Recommend completion of the commissioning process to the Project Manager.
11. Assist the GC in coordinating the training of owner personnel.

Note: If the CA is hired by the CM or directly by GSA, some or all of the CM tasks for the commissioning process above become the responsibility of the CA, as the need for oversight of the CA is essentially eliminated. Refer to further detail in the CM definition in Section 1.6, except for the coordination of deficiency resolution.

Warranty Period

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

G. Owner's Project Manager (PM)

Construction and Acceptance Phase

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

Warranty Period

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

H. General Contractor (GC)

Construction and Acceptance Phase

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

Warranty Period

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

I. Equipment Suppliers

1. Provide all requested submittal data, including detailed start-up procedures and specific responsibilities of the Owner to keep warranties in force.
2. Assist in equipment testing per agreements with Subs.
3. Include all special tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment according to these Contract Documents in the base bid price to the Contractor, except for stand-alone datalogging equipment that may be used by the CA.
4. Provide information requested by CA regarding equipment sequence of operation and testing procedures.
5. Review test procedures for equipment installed by factory representatives.

1.6 DEFINITIONS

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

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

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

Basis of Design - The 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.

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

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

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

Contractor - the general contractor or authorized representative.

Control system - the central building energy management control system.

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

b) When the CA is hired by the GC or A/E, the CM referred to in the commissioning process is a member of the CM team (staff or independent contractor) who shall have direct significant mechanical engineering and commissioning experience. That person designated from the CM team is the owner's representative verifying the adequacy of the commissioning process. In this case, the

CM will be more involved in the commissioning work and in witnessing portions of the process (selected start-up and functional tests) and reviewing documents (test approvals, etc.) than in the following case.

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

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

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

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

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

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

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

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

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

GSA - the General Services Administration (of the Federal Government)—the owner.

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

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

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

Non-Compliance - see Deficiency.

Non-Conformance - see Deficiency.

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

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

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

Prefunctional Checklist (PC) - a list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the CA to the Sub. 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, contractors typically perform some, if not many, of the prefunctional checklist items a commissioning agent will recommend. However, few contractors document in writing the execution of these checklist items. Therefore, for most equipment, the contractors execute the checklists on their own. The commissioning agent only requires that the procedures be documented in writing, and does not witness much of the prefunctional checklisting, except for larger or more critical pieces of equipment.

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

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

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

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

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

Specifications - the construction specifications of the Contract Documents.

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

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

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

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

Trending - monitoring using the building control system.

Vendor - supplier of equipment.

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

1.7 SYSTEMS TO BE COMMISSIONED

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

Equipment and System	Functional Test Requirements Specified In:	Equipment and System	Functional Test Requirements Specified In:
<u>HVAC System</u>	15997	___ Equipment vibration control	15997
___ Chillers	15997	___ Egress pressurization	15997
___ Pumps	15997	<u>Electrical System</u>	
___ Cooling tower	15997	___ Sweep or scheduled lighting controls	16997
___ Boilers	15997	___ Daylight dimming controls	16997
___ Piping systems	15997	___ Lighting occupancy sensors	16997
___ Ductwork	15997	___ Power quality	16997
___ Variable frequency drives	15997	___ Security system	16997
___ Air handlers	15997	___ Emergency power system	16997
___ Packaged units (AC and HP)	15997	___ UPS systems	16997
___ Terminal units (air)	15997	___ Fire and smoke alarm	16997
___ Unit heaters	15997	___ Fire protection systems	16997
___ Heat exchangers	15997	___ Communications system	16997
___ Computer room units	15997	___ Public address/paging	16997
___ Fume hoods	15997		
___ Lab room pressures	15997	<u>Other</u>	
___ Specialty fans	15997	___ Service water heaters	15997
___ Testing, Adjusting and Balancing work	15997	___ Service water booster pumps	15997
___ Chemical treatment systems	15997	___ Refrigeration systems	15997
___ HVAC control system	15997	___ Medical gas systems	15997
___ Fire and smoke dampers	15997		
___ Indoor air quality ¹	15997		
___ Equipment sound control	15997		

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

PART 2 - PRODUCTS

2.1 TEST EQUIPMENT

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

PART 3 - EXECUTION

3.1 MEETINGS

- A. Scoping Meeting. Within [60 to 90, depending on bldg size] days of commencement of construction, the CA will schedule, plan and conduct a commissioning scoping meeting with the entire commissioning team in attendance. Meeting minutes will be distributed to all parties by the CA. Information gathered from this meeting will allow the CA to revise the Draft 2 *Commissioning Plan* to its "final" version, which will also be distributed to all parties.
- B. Miscellaneous Meetings. Other meetings will be planned and conducted by the CA as construction progresses. These meetings will cover coordination, deficiency resolution and planning issues with particular Subs. The CA will plan these meetings and will minimize unnecessary time being spent by Subs. For large projects, these meetings may be held monthly, until the final 3 months of construction when they may be held as frequently as one per week.

3.2 REPORTING

- A. The CA will provide regular reports to the CM or PM, depending on the management structure, with increasing frequency as construction and commissioning progresses. Standard forms are provided and referenced in the *Commissioning Plan*.
- B. The CA will regularly communicate with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling changes through memos, progress reports, etc.
- C. Testing or review approvals and non-conformance and deficiency reports are made regularly with the review and testing as described in later sections.
- D. A final summary report (about four to six pages, not including backup documentation) by the CA will be provided to the CM or PM, focusing on evaluating commissioning process issues and identifying areas where the process could be improved. All acquired documentation, logs, minutes, reports, deficiency lists, communications, findings, unresolved issues, etc., will be compiled in appendices and provided with the summary report. Prefunctional checklists, functional tests and monitoring reports will not be part of the final report, but will be stored in the Commissioning Record in the O&M manuals.

3.3 SUBMITTALS

- A. The CA will provide appropriate contractors 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 Agent. All documentation requested by the CA will be included by the Subs in their O&M manual contributions.
- B. The Commissioning Agent 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 Commissioning Agent 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 require resubmission.
- C. The CA may request additional design narrative from the A/E and Controls Contractor, depending on the completeness of the design intent documentation and sequences provided with the Specifications.
- D. These submittals to the 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.

These guide specifications presume that design documentation and sequences of operation were carefully and completely prepared prior to bid documents being issued. If this was not the case, include language that requires that A/E and Controls Contractor to develop the design narrative and operating parameters according to the *Design Phase Commissioning Plan* and the format provided in Appendix 1 of that plan.

3.4 START-UP, PREFUNCTIONAL CHECKLISTS AND INITIAL CHECKOUT

- A. The following procedures apply to all equipment to be commissioned, according to Section 1.7, Systems to be Commissioned. Some systems that are not comprised so much of actual dynamic machinery, e.g., electrical system power quality, may have very simplified PCs and startup.
- B. General. Prefunctional checklists are important to ensure that the equipment and systems are hooked up and operational. It ensures that functional performance testing (in-depth system checkout) may proceed without unnecessary delays. Each piece of equipment receives full prefunctional checkout. No sampling strategies are used. The prefunctional testing for a given system must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.
- C. Start-up and Initial Checkout Plan. The CA shall assist the commissioning team members responsible for startup of any equipment in developing detailed start-up plans for all equipment. The primary role of the CA in this process is to ensure that there is written documentation that each of the manufacturer-recommended procedures have been completed. Parties responsible for prefunctional checklists and startup are identified in the commissioning scoping meeting and in the checklist forms. Parties responsible for executing functional performance tests are identified in the testing requirements in Sections 15997, 16997 and [list other sections where tests requirements are found].
 - 1. The CA adapts, if necessary, the representative prefunctional checklists and procedures from Section 15998. These checklists indicate required procedures to be executed as part of startup and initial checkout of the systems and the party responsible for their execution.
 - 2. These checklists and tests are provided by the CA to the Contractor. The Contractor determines which trade is responsible for executing and documenting each of the line item tasks and notes that trade on the form. Each form will have more than one trade responsible for its execution.
 - 3. The subcontractor responsible for the purchase of the equipment develops the full start-up plan by combining (or adding to) the CA's checklists with the manufacturer's detailed start-up and checkout procedures from the O&M manual and the normally used field checkout sheets. The plan will include checklists and procedures with specific boxes or lines for recording and documenting the checking and inspections of each procedure and a summary statement with a signature block at the end of the plan.

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

- a. The CA's prefunctional checklists.

- b. The manufacturer's standard written start-up procedures copied from the installation manuals with check boxes by each procedure and a signature block added by hand at the end.
- c. The manufacturer's normally used field checkout sheets.
- 4. The subcontractor submits the full startup plan to the CA for review and approval.
- 5. The CA reviews and approves the procedures and the format for documenting them, noting any procedures that need to be added.
- 6. The full start-up procedures and the approval form may be provided to the CM for review and approval, depending on management protocol.

An alternative to the process for developing the start-up plan given in parts 3-5 immediately above consists of the CA doing more of the work as described below.

OPTION FOR 3 - 5 ABOVE:

- a. The CA, (instead of the contractor), copies the manufacturer's startup and initial checkout procedures from O&M submittals.
 - b. The CA marks the applicable areas in the procedures and makes initial and date lines at each procedure or section.
 - c. The CA transmits these procedures and the original prefunctional checklist procedures (see 1 above) to the Contractor as the startup and initial checkout plan.
- D. Sensor Calibration. Calibration of all sensors shall be included as part of the prefunctional checklists performed by the Contractors, according to the following procedures:
- 1. All Sensors. Verify that sensors with shielded cable, are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, make sure they are reading within 0.2°F of each other for temperature and within a tolerance equal to 2% of the reading, of each other, for pressure. Tolerances for critical applications may be tighter.
 - 2. Sensors Without Transmitters—Standard Application. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, install offset in BAS, calibrate or replace sensor.
 - 3. Sensors With Transmitters—Standard Application. Disconnect sensor. Connect a signal generator in place of sensor. Connect ammeter in series between transmitter and BAS control panel. Using manufacturer's resistance-temperature data, simulate minimum desired temperature. Adjust transmitter potentiometer zero until 4 mA is read by the ammeter. Repeat for the maximum temperature matching 20 mA to the potentiometer span or maximum and verify at the BAS. Reconnect sensor. Make a reading with a calibrated test instrument within 6 inches of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage or building automation system (BAS)) is within the tolerances in the table below of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable signal generator.
 - 4. Critical Applications. For critical applications (process, manufacturing, etc.) more rigorous calibration techniques may be required for selected sensors. Describe any such methods used on an attached sheet.

<u>Sensor</u>	<u>Required Tolerance (+/-)</u>	<u>Sensor</u>	<u>Required Tolerance (+/-)</u>
Cooling coil, chilled and condenser water temps	0.3F	Flow rates, water	4% of design
AHU wet bulb or dew point	1.0F	Combustion flue temps	5.0F
Hot water coil and boiler water temp	1.0F	Oxygen or CO ₂ monitor	0.1 % pts
Outside air, space air, coil air temps	0.5F	CO monitor	0.01 % pts
Watt-hour, voltage & amperage	1% of design	Natural gas and oil flow rate	1% of design
Pressures, air, water and gas	3% of design	Steam flow rate	3% of design
Flow rates, air	10% of design	Barometric pressure	0.1 in. of Hg

E. Execution of Prefunctional Checklists and Startup.

1. Four weeks prior to startup, the Subs and vendors schedule startup and checkout with the CM, GC and CA. The performance of the prefunctional checklists, startup and checkout are directed and executed by the Sub or vendor. When checking off prefunctional checklists, signatures may be required of other Subs for verification of completion of their work.
2. The CA shall observe, at minimum, the procedures for each piece of primary equipment, unless there are multiple units, (in which case a sampling strategy may be used as approved by the CM). In no case will the number of units witnessed be less than four on any one building, nor less than 20% of the total number of identical or very similar units.
3. For lower-level components of equipment, (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the prefunctional and start-up procedures. The sampling procedures are identified in the commissioning plan.
4. The Subs and vendors shall execute startup and provide the CA with a signed and dated copy of the completed start-up and prefunctional tests and checklists.
5. Only individuals that have direct knowledge and witnessed that a line item task on the prefunctional checklist was actually performed shall initial or check that item off. It is not acceptable for witnessing supervisors to fill out these forms.

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

1. The Subs shall clearly list any outstanding items of the initial start-up and prefunctional procedures that were not completed successfully, at the bottom of the procedures form or on an attached sheet. The procedures form and any outstanding deficiencies are provided to the CA within two days of test completion.
2. The CA reviews the report and submits either a non-compliance report or an approval form to the Sub or CM. The CA shall work with the Subs and vendors to correct and retest deficiencies or uncompleted items. The CA will involve the CM and others as necessary. The installing Subs or vendors shall correct all areas that are deficient or incomplete in the checklists and tests in a timely manner, and shall notify the CA as soon as outstanding items have been corrected and resubmit an updated start-up report and a Statement of Correction on the original non-compliance report. When satisfactorily completed, the CA recommends

approval of the execution of the checklists and startup of each system to the CM using a standard form.

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

3.5 PHASED COMMISSIONING

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

3.6 FUNCTIONAL PERFORMANCE TESTING

- A. This sub-section applies to all commissioning functional testing for all divisions.
- B. The general list of equipment to be commissioned is found in Section 17100, Part 1.4. The specific equipment and modes to be tested are found in Sections 15997, 16997 and ____ [list other sections where tests requirements are found] ____.
- C. The parties responsible to execute each test are listed with each test in Sections 15997, 16997 and ____ [list other sections where tests requirements are found] ____.
- D. Objectives and Scope. The objective of functional performance testing is to demonstrate that each system is operating according to the documented design intent and Contract Documents. Functional testing facilitates bringing the systems from a state of substantial completion to full dynamic operation. Additionally, during the testing process, areas of deficient performance are identified and corrected, improving the operation and functioning of the systems.

In general, each system should be operated through all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in the sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested. Specific modes required in this project are given in Sections 15997, 16997 and ____ [list other sections where tests requirements are found] ____.

- E. Development of Test Procedures. Before test procedures are written, the CA shall obtain all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, program code, control sequences and parameters. Using the testing parameters and requirements in Sections 15997, 16997 and ____ [list other sections where tests requirements are found] ____ the CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Each Sub or vendor responsible to execute a test, shall provide limited assistance to the CA in developing the procedures review (answering questions about equipment, operation, sequences, etc.). Prior to execution, the CA shall provide a copy of the test procedures to the Sub(s) who shall review the tests for feasibility, safety, equipment and warranty protection. The CA may submit the tests to the A/E for review, if requested.

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

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

Representative test formats and examples (not designed for this facility) are found in the appendices to Divisions 15 and 16. The test procedure forms developed by the CA shall include (but not be limited to) the following information:

1. System and equipment or component name(s)
2. Equipment location and ID number
3. Unique test ID number, and reference to unique prefunctional checklist and start-up documentation ID numbers for the piece of equipment
4. Date
5. Project name
6. Participating parties
7. A copy of the specification section describing the test requirements
8. A copy of the specific sequence of operations or other specified parameters being verified
9. Formulas used in any calculations
10. Required pre-test field measurements
11. Instructions for setting up the test.
12. Special cautions, alarm limits, etc.
13. Specific step-by-step procedures to execute the test, in a clear, sequential and repeatable format
14. 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.
15. A section for comments
16. Signatures and date block for the CA

F. Test Methods.

1. Functional performance testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone dataloggers. Sections 15997, 16997 and [list other sections where tests requirements are found] specify which methods shall be used for each test. The CA may substitute specified methods or require an additional method to be executed, other than what was specified, with the approval of the CM. This may require a change order and adjustment in charge to the Owner. The CA will determine which method is most appropriate for tests that do not have a method specified.
2. Simulated Conditions. Simulating conditions (not by an overwritten value) shall be allowed, though timing the testing to experience actual conditions is encouraged wherever practical.
3. Overwritten Values. Overwriting sensor values to simulate a condition, such as overwriting the outside air temperature reading in a control system to be something other than it really is, shall be allowed, but shall be used with caution and avoided when possible. Such testing methods often can only test a part of a system, as the interactions and responses of other

systems will be erroneous or not applicable. Simulating a condition is preferable. e.g., for the above case, by heating the outside air sensor with a hair blower rather than overwriting the value or by altering the appropriate setpoint to see the desired response. Before simulating conditions or overwriting values, sensors, transducers and devices shall have been calibrated.

4. Simulated Signals. Using a signal generator which creates a simulated signal to test and calibrate transducers and DDC constants is generally recommended over using the sensor to act as the signal generator via simulated conditions or overwritten values.
5. Altering Setpoints. Rather than overwriting sensor values, and when simulating conditions is difficult, altering setpoints to test a sequence is acceptable. For example, to see the AC compressor lockout work at an outside air temperature below 55F, when the outside air temperature is above 55F, temporarily change the lockout setpoint to be 2F above the current outside air temperature.
6. Indirect Indicators. Relying on indirect indicators for responses or performance shall be allowed only after visually and directly verifying and documenting, over the range of the tested parameters, that the indirect readings through the control system represent actual conditions and responses. Much of this verification is completed during prefunctional testing.
7. Setup. Each function and test shall be performed under conditions that simulate actual conditions as close as is practically possible. The Sub executing the test shall provide all necessary materials, system modifications, etc. to produce the necessary flows, pressures, temperatures, etc. necessary to execute the test according to the specified conditions. At completion of the test, the Sub shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test condition.
8. Sampling. Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. Significant application differences and significant sequence of operation differences in otherwise identical equipment invalidates their common identity. A small size or capacity difference, alone, does not constitute a difference. The specific recommended sampling rates are specified with each type of equipment in Sections 15997, 16997 and [list other sections where test requirements are found]. It is noted that no sampling by Subs is allowed in prefunctional checklist execution.

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

xx = the percent of the group of identical equipment to be included in each sample.
yy = the percent of the sample that if failing, will require another sample to be tested.

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

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

- G. Coordination and Scheduling. The Subs 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, GC and affected Subs. The CA shall direct, witness and document the functional testing of all equipment and systems. The Subs shall execute the tests.

In general, functional testing is conducted after 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.

- H. Test Equipment. Refer to Section 17100, Part 2 for test equipment requirements.
- I. Problem Solving. The CA will recommend solutions to problems found, however the burden of responsibility to solve, correct and retest problems is with the GC, Subs and A/E.

3.7 DOCUMENTATION, NON-CONFORMANCE AND APPROVAL OF TESTS

- A. Documentation. The CA shall witness and document the results of all functional performance tests using the specific procedural forms developed for that purpose. Prior to testing, these forms are provided to the CM for review and approval and to the Subs for review. The CA will include the filled out forms in the O&M manuals.
- B. Non-Conformance.
1. The CA will record the results of the functional test on the procedure or test form. All deficiencies or non-conformance issues shall be noted and reported to the CM on a standard non-compliance form.
 2. 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.
 3. Every effort will be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. However, the 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.
 4. As tests progress and a deficiency is identified, the CA discusses the issue with the executing contractor.
 - a. When there is no dispute on the deficiency and the Sub accepts responsibility to correct it:
 - 1) The CA documents the deficiency and the Sub's response and intentions and they go on to another test or sequence. After the day's work, the CA submits the non-compliance reports to the CM for signature, if required. A copy is provided to the Sub and CA. The Sub corrects the deficiency, signs the statement of correction at the bottom of the non-compliance form certifying that the equipment is ready to be retested and sends it back to the CA.
 - 2) 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) The deficiency shall be documented on the non-compliance form with the Sub's response and a copy given to the CM and to the Sub representative assumed to be responsible.
 - 2) Resolutions are made at the lowest management level possible. Other parties are brought into the discussions as needed. Final interpretive authority is with the A/E. Final acceptance authority is with the Project Manager.
 - 3) The CA documents the resolution process.
 - 4) Once the interpretation and resolution have been decided, the appropriate party corrects the deficiency, signs the statement of correction on the non-compliance form and provides it to the CA. The CA reschedules the test and the test is repeated until satisfactory performance is achieved.
 5. Cost of Retesting.
 - a. The cost for the Sub to retest a prefunctional or functional test, if they are responsible for the deficiency, shall be theirs. If they are not responsible, any cost recovery for retesting costs shall be negotiated with the GC.

- b. For a deficiency identified, not related to any 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" to the GC for their time. However, the CA's and CM's time for a second retest will be charged to the GC, who may choose to recover costs from the responsible Sub.
 - c. The time for the CA and CM to direct any retesting required because a specific *prefunctional* checklist or start-up test item, reported to have been successfully completed, but determined during functional testing to be faulty, will be backcharged to the GC, who may choose to recover costs from the party responsible for executing the faulty prefunctional test.
 - d. Refer to the sampling section of Section 17100, Part 3.6 for requirements for testing and retesting identical equipment.
- 6. The Contractor shall respond in writing to the CA and CM at least as often as commissioning meetings are being scheduled concerning the status of each apparent outstanding discrepancy identified during commissioning. Discussion shall cover explanations of any disagreements and proposals for their resolution.
- 7. The CA retains the original non-conformance forms until the end of the project.
- C. Failure Due to Manufacturer Defect. If 10%, or three, whichever is greater, of identical pieces (size alone does not constitute a difference) of equipment fail to perform to the Contract Documents (mechanically or substantively) due to manufacturing defect, not allowing it to meet its submitted performance spec, all identical units may be considered unacceptable by the CM or PM. In such case, the Contractor shall provide the Owner with the following:
 - a. Within one week of notification from the CM or PM, the Contractor or manufacturer's representative shall examine all other identical units making a record of the findings. The findings shall be provided to the CM or PM within two weeks of the original notice.
 - b. Within two weeks of the original notification, the Contractor or manufacturer shall provide a signed and dated, written explanation of the problem, cause of failures, etc. and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation.
 - c. The CM or PM will determine whether a replacement of all identical units or a repair is acceptable.
 - d. Two examples of the proposed solution will be installed by the Contractor and the CM will be allowed to test the installations for up to one week, upon which the CM or PM will decide whether to accept the solution.
 - e. Upon acceptance, the Contractor and/or manufacturer shall replace or repair all identical items, at their expense and extend the warranty accordingly, if the original equipment warranty had begun. The replacement/repair work shall proceed with reasonable speed beginning within one week from when parts can be obtained.
- D. Approval. The CA notes each satisfactorily demonstrated function on the test form. Formal approval of the functional test is made later after review by the CA and by the CM, if necessary. The CA recommends acceptance of each test to the CM using a standard form. The CM gives final approval on each test using the same form, providing a signed copy to the CA and the Contractor.

3.8. OPERATION AND MAINTENANCE MANUALS

The following O&M documentation requirements assume that the general contractor is compiling the O&M manuals, with all Subs compiling their own sections, including some submissions for the A/E and CA.

These requirements may need to be merged and edited to follow the protocols and scope of the current agency or project. However, the comprehensiveness and accessibility described herein shall be maintained.

A. Standard O&M Manuals.

1. The specific content and format requirements for the standard O&M manuals are detailed in Section 01730. Special requirements for the controls contractor and TAB contractor are found Section 15995, Part 3.6.
2. A/E Contribution. The A/E will include in the beginning of the O&M manuals a separate section describing the systems including:
 - a. The design intent narrative prepared by the A/E and provided as part of the bid documents, updated to as-built status by the A/E.
 - b. Simplified professionally drawn single line system diagrams on 8 1/2" x 11" or 11" x 17" sheets. These shall include chillers, water system, condenser water system, heating system, supply air systems, exhaust systems and _____. These shall show major pieces of equipment such as pumps, chillers, boilers, control valves, expansion tanks, coils, service valves, etc.
3. CA Review and Approval. Prior to substantial completion, the CA shall review the O&M manuals, documentation and redline as-builds *for systems that were commissioned* and [list other systems documentation that the CA should review] 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.

B. Commissioning Record in O&M Manuals.

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

Tab I-1 Commissioning Plan

Tab I-2 Final Commissioning Report

Tab 01 System Type 1 (chiller system, packaged unit, boiler system, etc.)

Sub-Tab A Design narrative and criteria, sequences, approvals for Equipment 1

Sub-Tab B Startup plan and report, approvals, corrections, blank prefunctional checklists

Colored Separator Sheets—for each equipment type (fans, pumps, chiller, etc.)

Sub-Tab C Functional tests (completed), trending and analysis, approvals and corrections, training plan, record and approvals, blank functional test forms and a recommended recommissioning schedule.

Tab 02 System Type 2.....repeat as per System 1

2. Other documentation will be retained by the CA.

3.9 TRAINING OF OWNER PERSONNEL

- A. The GC shall be responsible for training coordination and scheduling and ultimately for ensuring that training is completed.
- B. The CA shall be responsible for overseeing and approving the content and adequacy of the training of Owner personnel for commissioned equipment.
 1. The CA shall interview the 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 Subs and vendors who have training responsibilities.
 2. In addition to these general requirements, the specific training requirements of Owner personnel by Subs and vendors is specified in Division 15 and 16 and [list other sections where training requirements are found].
 3. Each Sub and vendor responsible for training will submit a written training plan to the CA for review and approval prior to training. The plan will cover the following elements:
 - a. Equipment (included in training)
 - b. Intended audience
 - c. Location of training
 - d. Objectives
 - e. Subjects covered (description, duration of discussion, special methods, etc.)
 - f. Duration of training on each subject
 - g. Instructor for each subject
 - h. Methods (classroom lecture, video, site walk-through, actual operational demonstrations, written handouts, etc.)
 - i. Instructor and qualifications
 4. For the primary HVAC equipment, the Controls Contractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training conducted by others.
 5. The CA develops an overall training plan and coordinates and schedules, with the CM and GC, the overall training for the commissioned systems. The CA develops criteria for determining that the training was satisfactorily completed, including attending some of the training, etc. The CA recommends approval of the training to the CM using a standard form. The CM also signs the approval form.
 6. At one of the training sessions, the CA presents a ____ hour presentation discussing the use of

the blank functional test forms for re-commissioning equipment.

7. Video taping of the training sessions will be provided by ____ the Owner, ____ the CA with tapes cataloged by ____ the Owner, ____ the CA and added to the O&M manuals.
8. The mechanical design engineer shall at the first training session present the overall system design concept and the design concept of each equipment section. This presentation shall be ____ hours in length and include a review of all systems using the simplified system schematics (one-line drawings) including chilled water systems, condenser water or heat rejection systems, heating systems, fuel oil and gas supply systems, supply air systems, exhaust system and outside air strategies.

3.10 DEFERRED TESTING

- A. Unforeseen Deferred Tests. If any check or test cannot be completed due to the building structure, required occupancy condition or other deficiency, execution of checklists and functional testing may be delayed upon approval of the PM. These tests will be conducted in the same manner as the seasonal tests as soon as possible. Services of necessary parties will be negotiated.
- B. Seasonal Testing. During the warranty period, seasonal testing (tests delayed until weather conditions are closer to the system's design) specified in Section 15997 shall be completed as part of this contract. The CA shall coordinate this activity. Tests will be executed, documented and deficiencies corrected by the appropriate Subs, with facilities staff and the CA witnessing. Any final adjustments to the O&M manuals and as-builds due to the testing will be made.

3.11 WRITTEN WORK PRODUCTS

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

<u>Product</u>	<u>Developed By</u>
1. Final commissioning plan	CA
2. Meeting minutes	CA
3. Commissioning schedules	CA with GC and CM
4. Equipment documentation submittals	Subs
5. Sequence clarifications	Subs and A/E as needed
5. Prefunctional checklists	CA (already in Specs)
6. Startup and initial checkout plan	Subs and CA (compilation of existing documents)
7. Startup and initial checkout forms filled out	Subs
8. Final TAB report	TAB
9. Issues log (deficiencies)	CA
10. Commissioning Progress Record	CA
11. Deficiency reports	CA
12. Functional test forms	CA

<u>Product</u>	<u>Developed By</u>
13. Filled out functional tests	CA
14. O&M manuals	Subs
15. Commissioning record book	CA
16. Overall training plan	CA and CM
17. Specific training agendas	Subs
18. Final commissioning report	CA
19. Misc. approvals	CA

END OF GUIDE SPECIFICATION SECTION

Part IV

Model Commissioning Plan
--Construction Phase--

Sponsored by
US Department of Energy
Seattle Regional Support Office
800 5th Ave. Suite 3950
Seattle, WA 98104

Prepared by:
Portland Energy Conservation, Inc. (PECI)
921 SW Washington, Suite 312
Portland, OR 97205
503-248-4636, Fax 503-295-0820

Version 2.02

March 1997

Part IV. Model Commissioning Plan–Construction Phase

Summary

The *Commissioning Plan–Construction Phase* is developed in draft form for the specific project during the design phase. During the design phase, the plan provides direction for the development of the site-specific commissioning specifications by the design team. During the construction phase, the plan provides direction for the commissioning tasks during construction. The plan focuses on providing support for the specifications and provides forms for the application of the commissioning process.

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Commissioning Plan—Construction Phase

Project: _____

GSA Contact: _____

Date: _____

Cx Plan Version

___ Draft 1—Design Phase

___ Draft 2—Bid Documents

___ Final Cx Plan

Plan Approved: _____

Signature Title Date

1. Overview

1.1 Abbreviations and Definitions

The following are common abbreviations used in this document. Definitions are found in Division 17 of the Specifications.

A/E-	Architect and design engineers	FT-	Functional performance test
CA-	Commissioning agent	GC-	General contractor
CC-	Controls contractor	MC-	Mechanical contractor
CM-	Construction Manager	PC-	Prefunctional checklist
Cx-	Commissioning	PM-	Project manager (GSA)
Cx Plan-	Commissioning Plan document	Subs-	Subcontractors to General
EC-	Electrical contractor	TAB-	Test and balance contractor

Section Headings with “[Bid Docs]” at the right margin denote sections which include blanks that should be filled in prior to construction bidding. Other fill-in blanks are not filled in until after construction begins.

1.2 Purpose of The Commissioning Plan

The purpose of the construction phase commissioning plan is to:

1. Provide direction for the development of the Cx specifications by A/E, during the latter part of the design phase.
2. Provide direction for the commissioning process during construction, particularly providing resolution for issues and providing details that cannot be, or were not, fully developed during design, such as scheduling, participation of various parties of this particular project, actual lines of reporting and approvals, coordination, etc.

This plan does not provide a detailed explanation of required testing procedures. The detailed testing requirements and procedures are found in the Specifications, Sections 15997, 15998, 16997 and 16998. Additionally, this plan does not provide extensive narrative on all commissioning concepts, as may be provided in other commissioning guides.

1.3 Commissioning Scope

Commissioning is a systematic process of ensuring that all building systems perform interactively according to the design intent and the owner's operational needs. This is achieved by beginning in the design phase, documenting the design intent and continuing through construction, acceptance and the warranty period with actual verification of performance.

Commissioning during the construction of this project is intended to achieve the following specific objectives:

According to the Contract Documents:

- Ensure that applicable equipment and systems are installed properly and receive adequate operational checkout by installing contractors.
- Verify and document proper performance of equipment and systems.
- Ensure that O&M documentation left on site is complete.
- Ensure that the Owner's operating personnel are adequately trained.

1.4 Commissioned Systems

[Bid Docs]

The following marked systems will be commissioned in this project. Refer to Section 6 for additional details. All general references to equipment in this document refer only to equipment that is to be commissioned.

HVAC System (and all integral equipment controls)

- ☐ Chiller system (including controls, chillers, cooling towers, piping, pumps and variable speed drives)
- ☐ Boiler system (including controls, boilers, piping, pumps and variable speed drives)
- ☐ Pumps
- ☐ Variable speed drives
- ☐ Heat exchangers
- ☐ Piping, cleaning and flushing
- ☐ Chemical treatment
- ☐ Ductwork
- ☐ Air handling units
- ☐ Roof top packaged DX units (heatpumps or AC)
- ☐ Split systems
- ☐ Evaporative coolers
- ☐ Evaporative condensers
- ☐ Terminal units
- ☐ Testing, Adjusting and Balancing work
- ☐ Unit heaters
- ☐ Building automation system (controlled devices, control loops and system integration)

Electrical Systems

- ☐ Sweep and scheduled lighting controls
- ☐ Daylighting/dimming controls
- ☐ Electrical system power quality
- ☐ Communications system
- ☐ Security system
- ☐ Emergency power systems

☐ Uninterruptible power supply system

Life Safety Systems

- ☐ Fire alarm system
- ☐ Egress pressurization systems
- ☐ Fire suppression/protection systems

Plumbing

- ☐ Domestic booster pump
- ☐ Domestic hot water heaters
- ☐ _____

Laboratories/ Clinics

- ☐ Fume hoods
- ☐ Room isolation
- ☐ Process gas _____

Other

- ☐ Elevator
- ☐ Kitchen exhaust equipment
- ☐ Refrigeration equipment and systems
 - ☐ Walk-in coolers
 - ☐ Cases
 - ☐ Compressors and condensers
 - ☐ Control system
- ☐ _____
- ☐ _____

1.5 Forms

Forms used during commissioning are referred to in this plan by the format: Form D-xx or C-xx, where the "D" represents Design phase and "C" Construction phase. Blank versions as well as some sample filled- out versions are found in Appendix 1 of this plan.

2. General Building Information

[Bid Docs]

Project: _____

Location: _____

Building Type (office, court, etc.): _____

Square Footage: _____ Number of stories: _____

Agency: _____ Tenants: _____

Const. Period: _____

3. Construction/Cx Team Data (primary parties)

Team Member	Co. & Contact Names	Voice, office, cell, fax, email, address
Owner		
Project Manager		
Site Engineer		
Property Manager		
Construction Manager		
General Site Contact		
Mechanical		
General Contractor		
Site Supervisor		
Site Coordinator		
Commissioning Agent		
Architect		
Mechanical Designer/Eng.		
Electrical Designer/Eng.		
Tenant Representative		
Mechanical Contractor		
HVAC Site Superv.		
Piping Contractor		
Sheet Metal Contractor		
Electrical Contractor		
Site Supervisor		
TAB Contractor		
Controls Contractor		
Project Manager		
Project Engineer		

4. Roles and Responsibilities

4.1 Locations of Role Descriptions

[Bid Docs]

Descriptions and explanations of the roles and responsibilities of those in the commissioning process are found in the following places in the Contract Documents:

List of team members: *Cx Plan*, 4.2

Management plan outline: *Cx Plan*, 4.3. Specifications 17100, Pt. 1

General roles: *Cx Plan*, 4.4, Specifications 17100, Pt. 1

Specific responsibilities:

Information for all parties:	<i>Cx Plan</i> 5; <i>Specs</i> 17100, Pt. 1
CM, PM:	<i>Cx Plan</i> 5; <i>Specs</i> 17100, Pt. 1
Mechanical contractor, TAB, controls contractor, subs and mfr's:	<i>Specs</i> Div. 1 ¹ , 15995, 15990, 15997, 16998, 17100
Electrical contractor, subs and mfr's:	<i>Specs</i> Div. 1 ¹ , 16995, 16997, 16998, 17100
Commissioning agent:	<i>Specs</i> Div. 1 ¹ , 17100, 15 and 16997
A/E:	A/E contract, Div. 1 ¹ , <i>Specs</i> 17100

¹Division 1 sections include: 00800, 01040, 01300, 01700 and 10730.

4.2 Team Members

The members of the commissioning team consist of the CA, GSA PM, assigned members of the CM, GC, A/E (particularly the mechanical engineer), the mechanical contractor, electrical contractor, TAB representative, controls contractor, any other installing subcontractors or suppliers of equipment. If known, the Owner's building or plant operator/ engineer is also a member of the commissioning team.

4.3 General Management Plan

[Bid Docs]

The CA was hired by the ___CM, ___GC, ___A/E, ___GSA directly. In general, the CA coordinates the commissioning activities and reports to the ___CM, ___GC, ___A/E. The CA's responsibilities, along with all other contractors' commissioning responsibilities are detailed in the specifications. The Specifications will take precedence over this *Cx Plan*. All members work together to fulfill their contracted responsibilities and meet the objectives of the Contract Documents. Refer to the management protocols section below.

4.4 General Descriptions of Roles

General descriptions of the commissioning roles are as follows:

CA :	Coordinates the Cx process, writes tests, oversees and documents performance tests
CM :	Facilitates the Cx process. Approves test plans and signs-off on performance, if the CA was not hired by the CM.
GC :	Facilitates the Cx process, ensures that Subs perform their responsibilities and integrates Cx into the construction process and schedule

- Subs : Demonstrate proper system performance
- A/E : Perform construction observation, approve O&M manuals and assist in resolving problems
- PM : Facilitates and supports the Cx process and gives final approval of the Cx work
- Mfr. : The equipment manufacturers and vendors provide documentation to facilitate the commissioning work and perform contracted startup

5. Commissioning Process

This section sequentially details the commissioning process by commissioning task or activity.

5.1 Commissioning Scoping Meeting

[Bid Docs]

A commissioning scoping meeting is planned and conducted by the CA within ____ [90] days of the beginning of construction. In attendance are the respective representatives of the GC, CM, CA, PM, A/E and the mechanical, electrical, controls, and TAB subs. At the meeting commissioning parties are introduced and the commissioning process reviewed, management and reporting lines determined. The flow of documents, how much submittal data the CA will receive, etc. are also being discussed. The *Cx Plan* is reviewed, process questions are addressed, lines of reporting and communications determined and the work products list discussed. Also covered are the general list of each party's responsibilities, who is responsible to develop the startup plan for each piece of equipment (Form C-7, *Commissioning Progress Record*) and the proposed commissioning schedule. The outcome of the meeting is increased understanding by all parties of the commissioning process and their respective responsibilities. The meeting provides the CA additional information needed to finalize the *Cx Plan*, including the commissioning schedule.

Prior to this meeting the CA is given, by the GC, all drawings and specifications and the construction schedule by trade. The CA keeps notes from the meeting and distributes them to each team member.

5.2 Final Commissioning Plan–Construction Phase

[Bid Docs]

The CA finalizes the draft *Cx Plan* using the information gathered from the scoping meeting. The initial commissioning schedule is also developed (Table 8-1) along with a detailed timeline using Form C-10, *Detailed Commissioning Schedule*. The timeline is fine-tuned as construction progresses. In particular, ____ [60] days prior to startup of the primary equipment, the CA meets with the GC and CM and develops a detailed commissioning schedule. The commissioning plan is approved by the CM.

5.3 Site Observation

The CA, and CM if applicable, makes periodic visits to the site, as necessary, to witness equipment and system installations.

5.4 Miscellaneous Meetings

The CA attends selected planning and job-site meetings in order to remain informed on construction progress and to update parties involved in commissioning. The CM and GC provide the CA with information regarding substitutions, change orders and any Architect's Supplemental Instructions (ASI) that may affect commissioning equipment, systems or the commissioning schedule. The CA may review construction meeting minutes, change orders or ASIs for the same purpose.

Later during construction, necessary meetings between various commissioning team parties will be scheduled by the CA, through the CM, as required.

5.5 Miscellaneous Management Protocols

The following protocols will be used on this project.

<u>Issue</u>	<u>Protocol</u>
For requests for information (RFI) or formal documentation requests:	The CA goes first: ___ direct to Sub or A/E, ___ through the CM, ___ through GC.
For minor or verbal information and clarifications:	The CA goes direct to the informed party.
For notifying contractors of deficiencies:	The CA documents deficiencies through the CM, but may discuss deficiency issues with contractors prior to notifying the CM.
For scheduling functional tests or training:	___ The CA may provide input for and do some coordination of training and testing, but does not do any scheduling.
For scheduling commissioning meetings:	The CA selects the date and schedules through the: ___ CM, ___ GC. ___ The CA schedules and notifies attendees directly.
For making a request for significant changes:	The CA has no authority to issue change orders.
For making small changes in specified sequences of operations:	___ The CA may make small sequences of operations changes to improve efficiency or control or to correct deficiencies, through the responsible contractor, but shall document the change and provide all changes of specified sequences to the CM and A/E. ___ The CA may <u>not</u> make changes to specified sequences without approval from the A/E.
Subcontractors disagreeing with requests or interpretations by the CA shall:	Try and resolve with the CA first. Then work through GC who will work with CA directly or through the CM to resolve the situation.

Additional protocols regarding the flow of documents and the commissioning process are shown in Appendix 2.

5.6 Progress Reporting and Logs

At the beginning of construction, the CA provides the CM with monthly commissioning progress reports. Thirty (30) days prior to the startup of the first piece of major equipment, the frequency of progress reports is increased to twice per month, until startup is completed. Thirty (30) days before functional testing of equipment begins, weekly progress reports are required until functional testing and all non-conformance issues are resolved. The CM may adjust the reporting frequency as needed. The progress reports contain: an update of the schedule with list of requested schedule changes and new items added to the schedule, a list of new and outstanding deficiencies, a description of commissioning progress corresponding to the plan, etc. Form C-4, *Commissioning Progress Report* provides a format for this report. The CA keeps a log of all commissioning-related issues that require current or future attention using Form C-1, *Commissioning Issues Log*. Form C-7 *Commissioning Progress Record* provides a form for tracking the status of documentation and testing for each piece of equipment and system (e.g., installer, party responsible for

startup, approval dates for checklist and testing forms, their completion, training, O&M documentation review, etc.).

The CA regularly communicates with all members of the commissioning team, keeping them apprised of commissioning progress and scheduling issues through memos, progress reports, etc. (Form C-3e, *Commissioning Memorandum*).

The CA will keep all commissioning materials in an organized notebook. An example format is illustrated in Form C-17, *Sample Commissioning Record Notebook Format*, in Appendix 1.

5.7 Initial Submittals and Documentation

5.7.1 Standard Submittals

The CA provides all Subs responsible for commissioned equipment with commissioning documentation requirements for their respective equipment and systems through the CM. This data request typically coincides with the normal A/E submittal process. At minimum, this equipment data includes installation and start-up procedures, O&M data, performance data and control drawings. Form C-2, *Request for Documentation and Record of Submissions for Commissioning* provides documentation request and tracking forms for representative equipment and acts as the tracking mechanism for documentation. It can also be used as the checkoff sheet for part of the final O&M documentation review.

5.7.2 Special Submittals, Notifications and Clarifications

The Subs, GC or A/E notify the CA of any new design intent or operating parameter changes, added control strategies and sequences of operation, or other change orders that may affect commissioned systems. The controls contractor provides the CA a full points list with details requested by the CA (see Specs 17100, 3.3; 01300). Thirty (30) days prior to performing owner-contracted tests, the Subs provide the CA full details of the procedures. As the phases of the TAB are completed, the draft TAB report is provided to the CA with full explanations of approach, methods, results, data table legends, etc. The final TAB report is provided to the CA upon completion.

These submittals to the CA do not constitute compliance for submittals for the O&M manuals. Documentation requirements for the O&M manuals are discussed in Section 5.11, herein.

The CA may request additional design narrative from the A/E and from the controls contractor depending on how complete the documentation was which was provided with the bid documents. The CA may submit written RFIs to contractors through the CM, (Form C-3d, *Commissioning Request for Information*) or address them directly for clarifications, as needed.

5.8 Prefunctional Checklists, Tests and Startup

Prefunctional checklists (PC) are important to ensure that the equipment and systems are hooked up and operational and that functional performance testing may proceed without unnecessary delays. Each piece of equipment receives full prefunctional checkout by the Contractor. No sampling strategies are used. In general, the prefunctional testing for a given system, must be successfully completed prior to formal functional performance testing of equipment or subsystems of the given system.

Prefunctional checklists are primarily static inspections and procedures to prepare the equipment or system for initial operation (e.g., oil levels OK, fan belt tension, labels affixed, gages in place, sensor calibration, 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.

Contractors typically already perform some, if not many, of the prefunctional checklist items the commissioning agent will recommend. However, few contractors document in writing the execution of these checklist items. This project requires that the procedures be documented in writing by the installing technician. The CA does not witness much of the prefunctional checklist, except for testing of larger or more critical pieces of equipment and some spot-checking.

5.8.1 Start-up Plan

The CA assists the commissioning team members responsible for startup in developing detailed start-up plans for all equipment. The parties responsible for each part of startup and initial checkout are identified in Form C-7 *Commissioning Progress Record* and on the prefunctional checklists. Refer to Appendix 2, Chart 1 for a graphic description of how the prefunctional checklist and start-up plans are developed. Chart 3 in Appendix 2 shows a submittal map for reference.

A. ___ The following procedures will be used for this project: (the CA is responsible for the plan development):

1. The CA adapts and enhances, if necessary, the representative prefunctional checklists (PC) and procedures from the lists in Specification Section 15998, and develops original lists, as necessary.
2. The CA obtains manufacturer installation, startup and checkout data, including actual field checkout sheets used by the field technicians from the contractor (through an RFI).
3. The CA copies all pages with important instructional data and procedures from the startup and checkout manuals not covered in manufacturer field checkout sheets and adds a signature line in the column by each procedure.
4. The copied pages from (2), along with the prefunctional checklist provided by the CA and the manufacturer field checkout sheets become the "Startup and Checkout Plan." Form C-8, *Plan and Documenting Requirements for Startup*, provides a cover sheet and template for the startup plan.
5. For systems that may not have adequate manufacturer startup and checkout procedures, particularly for components being integrated with other equipment, the Sub should provide the added necessary detail and documenting format to the CA for approval, prior to execution.
6. The CA transmits the full Startup Plan to the GC, who designates which trade or contractor is responsible to fill out each line item (mark in the "Contr" column) on the Prefunctional Checklist from the CA. The GC then transmits the full start-up plan to the Subs for their review and use. (This usually means that the Prefunctional Checklist, alone, will go to more than one Sub, while the full plan will go to the primary installing contractor.)

—OR—

B. ___ The following procedures will be used for this project: (the Sub is responsible for the plan development):

1. The CA adapts and enhances, if necessary, the representative prefunctional checklists (PC) and procedures from the lists in Specification Section 15998, and develops original lists, as necessary.
2. The CA transmits them to the GC who designates which trade or contractor is responsible to fill out each line item (mark in the "Contr" column) on the Prefunctional Checklist from the CA. The GC then transmits the checklist to the responsible Subs.

3. The Sub designated to develop the Start-up Plan obtains manufacturer installation, start-up and checkout data, including actual field checkout sheets used by the field technicians.
4. The Sub copies all pages with important instructional data and procedures (not covered in manufacturer field checkout sheets) from the start-up and checkout manuals and adds a signature line in the column by each procedure.
5. The copied pages from (2), along with the prefunctional checklist provided by the GC (originally from the CA) and the manufacturer field checkout sheets become the “Start-up and Checkout Plan.” Form C-8, *Plan and Documenting Requirements for Startup*, provides a cover sheet and template for the start-up plan.
6. For systems that may not have adequate manufacturer start-up and checkout procedures, particularly for components being integrated with other equipment, the Sub should provide the added necessary detail and documenting format to the CA for approval, prior to execution.
7. The Sub transmits the full Start-up Plan to the CA for review and approval.
8. The CA reviews and approves the procedures and the format for documenting them using a standard form (Form C-3a or b, *Commissioning Test or Review Approval or Commissioning Prefunctional Checklist and Startup Submittal / Approval*), noting any procedures that need to be added, and conveys to the GC. The GC then transmits the full start-up plan to the Subs for their review and use. (This usually means that the Prefunctional Checklist, alone, will go to more than one Sub, while the full plan will go to the primary installing contractor.)

5.8.2 Execution of Checklists and Startup

Four weeks prior to startup, the Subs and vendors schedule startup and initial checkout with the CM, GC and CA. The startup and initial checkout are directed and executed by the Sub or vendor. The CA, and CM if necessary, observe, at minimum, the procedures for each piece of primary equipment, unless there are multiple units, when a sampling strategy is used. For components of equipment, (e.g., VAV boxes), the CA observes a sampling of the prefunctional and start-up procedures.

To document the process of startup and checkout, the site technician performing the line item task initials and dates each paragraph of procedures in the “Startup Plan” and checks off items on the prefunctional and manufacturer field checkout sheets, as they are completed. Only individuals having direct knowledge of a line item being completed shall check or initial the forms.

The Subs and vendors execute the checklists and tests and submit a signed copy of the completed start-up and prefunctional tests and checklists to the CA, using Form C-3a or b. Further details are found in the Specifications Section 17100, Part 3.4. The CA may review prefunctional checklists in progress, as necessary. On smaller equipment or projects, the checklists (which all contain more than one trade’s responsibility), may be passed around to the Subs to fill out. For larger projects, each trade may need a full form and the CA will consolidate them later.

5.8.3 Sampling Strategy for CA Observation of Prefunctional Checkout and Startup

The following table provides a tentative list of the equipment and how much of the prefunctional checkout and startup work will be witnessed by the commissioning agent.

<u>Equipment or System</u>	<u>Fraction To Be Observed by CA</u>
Central plant (chillers, boilers, cooling tower)	50%
Packaged roof top units	50%
Pumps, VFD’s	10%

Pipe flushing	At beginning and end
Terminal units	2%
Building automation system	Observe ____ hours of checkout and calibration
TAB work	Observe ____ hours of TAB
Other misc. equipment	As necessary

5.8.4 Deficiencies and Non-Conformance

The Subs clearly list any outstanding items of the initial start-up and prefunctional procedures that were not completed successfully at the bottom of the procedures form or on an attached sheet. The procedures form and deficiencies are provided to the CA within two days of test completion. The CA works with the Subs and vendors to correct and retest deficiencies or uncompleted items, involving the CM and others as necessary. The installing Subs or vendors correct all areas that are deficient or incomplete according to the checklists and tests. The CA recommends approval of the startup and initial checkout of each system to the CM using Form C-3a. Further details are found in the Specifications Section 17100, Part 3. Refer to Appendix 2, Chart 5 for a flow chart of the documentation process.

5.8.5 Phased Commissioning

Because of project size, this project ____ will require, ____ will not require startup and initial checkout to be executed in phases. The phasing is summarized in Form C-12, *Phased Commissioning*, in Appendix 1. Additional resolution of these phases can be found in the detailed commissioning schedule.

5.8.6 TAB

The TAB contractor submits the outline of the TAB plan and approach to the CA and the controls contractor eight weeks prior to starting the TAB. Included in the approach, is an explanation of the intended use of the building control system. The CA reviews the plan and approach for understanding and coordination issues and may comment, but does not “approve.” The controls contractor reviews the feasibility of using the building control system for assistance in the TAB work. The TAB submits weekly written reports of discrepancies, contract interpretation requests and lists of completed tests to the CA and CM. This facilitates quicker resolution of problems and will result in a more complete TAB before functional testing begins. A checklist form for reviewing the TAB plan is provided as one of the prefunctional checklists in Specifications Section 15998 (file: tabplan.c03).

TAB work will not begin until the control system has been prefunctionally tested and selective functional tests have been performed and approved by the CA.

5.8.7 Controls Checkout Plan

The controls contractor develops and submits a written step-by-step plan to the CA which describes the process they intend to follow in checking out the control system and the forms on which they will document the process. The controls contractor will also meet with the TAB contractor prior to the start of TAB and review the TAB plan to determine the capabilities of the control system for use in TAB. The controls contractor will provide the TAB with any necessary unique instruments for setting terminal unit boxes and instruct TAB in their use (handheld control system interface for use around the building during TAB, etc.).

The controls contractor shall also provide a technician qualified to operate the controls to assist the TAB contractor in performing TAB. Additional details are found in Specifications Section 15995.

All CA-required controls prefunctional checklists, calibrations, start-up and selected functional tests of the system shall be completed and approved by the CA prior to TAB. The controls contractor shall execute the

tests and trend logs assigned to them in Section 15997 and 16997 and remain on site for assistance for mechanical system functional tests as specified in the same sections.

5.9 Development of Functional Test and Verification Procedures

5.9.1 Overview

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 of the control system's sequences of operation and components are verified to be responding as the sequences state. The commissioning agent develops the functional test procedures in a sequential written form, coordinates, oversees and documents the actual testing, which is usually performed by the installing contractor or vendor.

5.9.2 Scope of Testing

[Bid Docs]

The specification "Testing Requirements" Sections 15997 and 16997 provide specific functional testing scope for each piece of commissioned equipment. A detailed description of the functional and prefunctional testing procedures and process is found in the Specifications, 17100 Part 3. If specific testing requirements were not included in the bid documents and original specifications, they should be developed for this project for each piece of commissioned equipment. Another example format, with less detail than in the Guide Specifications Sections 15997 and 16997, that may be useful is illustrated in Form C-15, *Functional Testing Scope Outline*.

5.9.3 Development Process

Before test procedures are written, the CA obtains all requested documentation and a current list of change orders affecting equipment or systems, including an updated points list, control sequences and setpoints. The CA develops specific test procedures to verify proper operation of each piece of equipment and system, using the testing requirements in the Specifications, Sections 17100 and Sections 15995, 15997, 16995 and 16997 and the representative test procedure formats found in Sections 15999 and 16999 and other sources. The CA obtains clarification, as needed, from contractors and the A/E regarding sequences and operation to develop these tests. Prior to execution, the CA provides a copy of the primary equipment tests to the installing Sub (via the GC) who reviews the tests for feasibility, safety, warranty and equipment protection. Blank copies of the procedures are input into the O&M manuals for later use by operations staff. Refer to Appendix 2, Chart 2 for an illustration of the development of functional test forms and Chart 4 for the functional test submittal map.

Functional testing and verification may be achieved by manual testing (persons manipulate the equipment and observe performance) or by monitoring the performance and analyzing the results using the control system's trend log capabilities or by stand-alone dataloggers. The CA follows the Specifications when given and uses judgement where needed to determine which method is most appropriate. According to the Specifications, not all pieces of identical equipment receive in-depth testing. The CA reviews owner-contracted, factory or required owner acceptance tests and determines what further testing may be required to comply with the Specifications. Redundancy is minimized.

Form C-13, *Owner Contracted Tests*, lists the owner-contracted or conducted tests for which the CA does not write procedures or document execution. Included in Form C-13 is the CA's judgement as to the rigor of the tests and the need for more in-depth testing. The CA reviews and approves documentation format of these tests prior to execution, but does not develop the procedures or document their execution, unless so requested by the CM.

5.9.4 Testing Plan Overview

To provide the contractors with a better idea of where functional testing lies in the schedule, what issues are preventing the start of testing, which contractors are needed for each test and how much time might be expected from them, Form C-11, *Commissioning Functional Testing Plan Overview*, is used. This form is filled out after most equipment has been started up and when functional testing dates are not too far off. The form is provided to the Contractors to assist in moving more efficiently to functional testing.

5.10 Execution of Functional Testing Procedures

5.10.1 Overview and Process

The CA schedules functional tests through the CM, GC and affected Subs. The CA oversees, witnesses and documents the functional testing of all equipment and systems according to the Specifications and the Cx Plan. The Subs execute the tests. The control system is tested before it is used 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 and finally to interlocks and connections between systems. Refer to Section 6 for details on functional testing scope. Refer to specification section 17100 Part 3 for additional process details and to Appendix 2, Chart 5, for a flow chart of the documentation process.

5.10.2 Deficiencies and Retesting

The CA documents the results of the test. Corrections of minor deficiencies identified are made during the tests at the discretion of the CA. The CA records the results of the test on the procedure or test form. Deficiencies or non-conformance issues are noted and reported to the CM on Form C-6 (*Commissioning Corrective Action Report*). Subs correct deficiencies, notify the CA and return Form C-6 certifying correction. The CA schedules retesting through the CM. Decisions regarding deficiencies and corrections are made at as low a level as possible, preferably between CA or CM and the Sub. For areas in dispute, final authority, besides the Owner's, resides with the A/E. The CA recommends acceptance of each test to the CM. The CM gives final approval on each test using Form C-3a or b (*Commissioning Test or Review Approval or Commissioning Prefunctional Checklist and Startup Submittal / Approval*) form. For tracking, Form C-7, *Commissioning Progress Record*, is provided which lists all tests and their status. Refer to Specifications Section 17100 Part 3.7 for further details.

5.10.3 Facility Staff Participation

The Owner's facilities operating staff are encouraged to attend and participate in the testing process. The tables in Form C-14, *Facility Staff Participation*, summarize the planning of their involvement. This form does not describe their involvement in formal training. The CA will notify the ___ CM, ___ PM, who will then notify the facility staff when the commissioning events will occur.

5.10.4 Phased Testing

Refer to Section 5.8.5 for details regarding testing the equipment or systems in phases.

5.10.5 Sampling

Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. The Specifications specify the sampling strategies that are used on this project, with a summary listed in Form C-15, *Functional Testing Scope Outline*, if used.

5.11 O&M Manuals and Warranties

5.11.1 Standard O&M Manuals

The CA reviews the O&M manuals, documentation and redline as-builts for systems that were commissioned to verify compliance with the Specifications. The CA recommends approval and acceptance of these sections of the O&M manuals to the CM. The CA also reviews each equipment warranty and verifies that all requirements to keep the warranty valid are clearly stated. Refer to Specifications 17100 Part 3.8 for further details.

5.11.2 Commissioning Record

The CA will compile, organize and index the following commissioning data by equipment into labeled, indexed and tabbed, three-ring binders and deliver it to the GC, to be included with the O&M manuals. The correspondence, meeting minutes and progress reports, miscellaneous notes, etc. kept in the Commissioning Record Book during construction will not be retained into this record and the O&M manuals. The format of the manual follows:

General

- Tab I-1* Commissioning Plan
- Tab I-2* Final Commissioning Report
- Tab I-3* Issues Log (record of deficiencies, Form C-1)
- Tab I-4* Progress Record (Form C-7)

Equipment Specific

- Tab 01* System Type 1 (chiller system, packaged unit, boiler system, etc.)
 - Sub-Tab A* Design narrative and criteria, sequences, approvals for Equipment 1
 - Sub-Tab B* Start-up plan and report, approvals, corrections, blank prefunctional checklists
Colored Separator Sheets—for each equipment type (fans, pumps, chiller, etc.)
 - Sub-Tab C* Functional tests (completed), trending and analysis, approvals and corrections, training plan, record and approvals, blank functional test forms and a recommended recommissioning schedule.
- Tab 02* System Type 2.....repeat as per System One

5.12 Training and Orientation of Owner Personnel

Owner training and orientation on equipment and systems provided by the Contractor is accomplished in three general steps using three forms.

1. Overall Plan. After reviewing the specifications, and after interviewing facility staff, if necessary, the Owner and Commissioning Agent (CA) fill out a table listing all the equipment for which training or orientation will be provided, on Form C-5a, *Project Training Plan—General Scope and Responsible Parties*. This form lists, among other things, the type and number of trainees, rigor of training desired by the Owner, the primary responsible subcontractor, the trainer's company and columns for tracking training agendas. The Commissioning agent provides this form to the Contractor for reference.
2. Specific Training Agendas. For each piece of equipment or system for which training is provided, the Owner and CA fill out Section 1 of the *Training and Orientation Agenda*, Form C-5b. This section includes some of the information from Form C-5a, regarding the scope of training and the intended audience, for reference by the trainer in developing the training agenda. The CA develops a plan for including in the training session contractors / trainers from different disciplines, when appropriate, by listing their company names in Section 2 of the form. In particular, the controls contractor will provide brief training on controls in the same session with the mechanical training for equipment controlled by the building automation system.

This form is then submitted to the Contractor who has the trainer fill out the rest of Sections 2 and 3 of the form (Form C-5b), describing the subjects covered, duration of each subject and the methods that will be used in the training, along with the name and qualifications of the trainer(s). The trainer returns this form to the Contractor, who submits it to the Owner and CA. The Owner and CA review the agenda; make comments; approve the form subject to the comments; and submit back to the Contractor. The Contractor provides the approved agenda to the trainer to use during the training. The trainer provides a copy of the agenda to each trainee.

3. **Training Record.** For each piece of equipment, prior to training, the Contractor provides each trainer Form C-5c, *Training and Orientation Record*. On this form, the trainer documents each training session (duration and general subjects covered). The trainer signs for the session and obtains the signature of each trainee. The trainer also checks off subjects covered on the Agenda (Form C-5b). When the training is complete, the Contractor provides a copy of the *Training and Orientation Record*, Form C-5c, and the trainer's Agenda, Form C-5b to the Owner and CA. The Owner and CA review C-5c and make final approval by signing it. The CA may witness any of the training sessions. Refer to Specifications 17100 Part 3.10 for further details.

5.12.1 Special Training and Orientation

The following checked orientation and trainings will be completed by the CA and A/E according to the specifications:

- ___ **Recommissioning.** The commissioning agent will provide instruction on the use of blank functional test forms for periodic recommissioning of equipment and systems, per the specification.
- ___ **Architect.** The architect will provide a general overview of the facility, its use, special features, tenant and public considerations, etc.
- ___ **Mechanical Design Engineer.** The mechanical designer will provide an overview of the major systems and equipment in the facility, including for each system: the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.
- ___ **Electrical Design Engineer.** The electrical designer will provide an overview of the major electrical systems and equipment in the facility, particularly the lighting control systems, fire alarm, security and emergency power, focusing on the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.

5.13 Warranty Period

During the warranty period, seasonal testing and other deferred testing required is completed according to the Specifications. The CA coordinates this activity. Tests are executed and deficiencies corrected by the appropriate Subs, witnessed by facilities staff and the CA. Any final adjustments to the O&M manuals and as-builts due to the testing are made. Refer to specification sections 15997 and 16997 for seasonal testing details for this project. In addition the CA will return to the project approximately 10 months into the 12 month warranty period. During this visit(s) the CA will review with facility staff the current building operation and the condition of outstanding issues related to the original and seasonal commissioning. The CA will also interview facility staff and identify problems or concerns they have operating the building as originally intended. The CA will make suggestions for improvements and for recording these changes in the O&M manuals. The CA will identify areas that may come under warranty or under the original construction contract. The CA will also assist facility staff in developing reports and documents and requests for services to remedy outstanding problems.

6. Written Work Products

[Bid Docs]

The written work products from all parties are described in Form C-16, *Formal Written Work Products*. The table describes each product, who is responsible for producing it, the general due date, the parties who receive it and who approves it, etc.

6.1 Summary Report

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

7. Schedule

7.1 General Issues

[Bid Docs]

The following sequential priorities are followed:

1. Equipment is not "temporarily" started (for heating or cooling), until pre-start checklist items and all manufacturer's pre-start procedures are completed and moisture, dust and other environmental and building integrity issues have been addressed.
2. Functional testing is not begun until prefunctional and start-up and TAB is completed, for a given system (this does not preclude a phased approach).
3. The controls system and equipment it controls are not functionally tested until all points have been calibrated and pre-functional testing completed.
4. TAB is not performed until the controls system has been sufficiently functionally tested and approved by the CA for TAB work, except for _____
5. TAB is not performed until the envelope is completely enclosed and ceiling complete, unless the return are is ducted.

7.2 Project Schedule

The initial commissioning schedule is summarized in Table 7-1. A more detailed schedule is contained in Form C-10, *Detailed Commissioning Schedule*, in Appendix 1.

Table 7-1. Initial Commissioning Schedule Summary

Task / Activity	Estimated Start Date	Estimated End Date
Initial scoping meeting and final plan		
Submittals obtained and reviewed		
Begin construction site visits/inspections		
Prefunctional forms developed and distributed		
Startup and initial checkout plans		
Startup and initial checkout executed		
TAB Water Air		
Functional performance tests		
O&M documentation review and verification		
Training and training verification		
Final commissioning report		
Seasonal testing		

Part IV

APPENDIX 1

Construction Phase Application Forms

<u>Form Number</u>	<u>Description</u>	<u>Name¹</u>
C-1	Commissioning Issues Log	ISSULOG.C01
C-2	Request for Documentation and Record of Submissions	DOCREQC2.XLS
C-3a	Commissioning Test or Review Approval	APPROVAL2.C3A
C-3b	Commissioning Prefunctional Check Submittal / Approval	PCSUBMIT.C3B
C-3c	Commissioning Transmittal	TRANSMIT.C3C
C-3d	Commissioning Request for Information	INFOREQ.C3D
C-3e	Commissioning Memorandum	MEMORAND.C3E
C-3f	Submittal for Sequences & Test Forms	SUBFTFRM.C3F
C-4	Commissioning Progress Report	PROGREPT.C04
Training	Project Training and Orientation Procedures	TRAINPRO.CED
C-5a	Overall Staff Training and Orientation Plan	TRAINPLN.C5A
C-5b	Training and Orientation Agenda	TRAINAGE.C5B
C-5c	Staff Training and Orientation Record	TRAINREC.C5C
C-6	Commissioning Corrective Action Report	CORECTON.C06
C-7	Commissioning Progress Record	RECORDC7.XLS
C-8	Plan and Documentation Requirements for Startup and Initial Checkout	STARTPLN.C08
C-9	Detailed Commissioning Schedule (blank)	TIMEBLC9.XLS
C-10	Detailed Commissioning Schedule (filled in)	TIMEFC10.XLS
C-11	Commissioning Functional Testing Plan Overview	FTOVRVU.C11
C-12	Phasing of Commissioning Testing	PHASES.C12
C-13	Owner-Contracted Tests	OWNRTEST.C13
C-14	Facility Staff Participation in Commissioning	STAFFPART.C14
C-15	Functional Testing Scope Outline (example)	SCOPEFILC15
C-16	Commissioning Formal Written Work Products	PRODUCTS.C16
C-17	Commissioning Record Notebook Format	BOOK_C17.XLS

COMMISSIONING ISSUES LOG

Attach additional pages as necessary for issues requiring more explanation and tracking.

Project: _____ Page _____ of _____
Prepared by: _____

#	Issue	Date Found	Effects	Possible Cause	Recommendations	Actions Taken	O&M Doc. Issue?	Fix (✓ or Date)

REQUEST FOR DOCUMENTATION AND RECORD OF SUBMISSIONS

Project: _____ Dates of Request: _____

Provide data for all BLANK or circled cells. Left ✓ or date = received. Right ✗ or date = approved. [d]

Send to: _____

Equip. Tag	Equipment Description	Spec Section	Part of Std. O&Ms			Part of Std. O&M Manual			Part of Cx Record			Part of Cx Record		
			Cut Sheets & Perform. Data [b]	Product Description Literature	Installation Guide & Shipped Data [c]	Start-up Guide & Checkout Plan	Any Req'd Test Plans [a]	O&M Booklet or Data	Warranty & Any Service Contract	Control Drawings & Points List	Ctrl. Sequences and Schedules	Design Intent & Basis of Design	Start-up Reports	Certifications (pressure, leaks, gas, gov't inspec.,)
PUMPS (HVAC)			Date needed by: _____			Include: pump curves w/ operating point								
	DHW circ. pump													
	DHW booster pump													
	Htg. primary													
	Htg. secondary													
	CHW primary													
	CHW secondary													
	CDW													
CHILLER SYSTEM			Date needed by: _____			Include: certified efficiencies								
	Chiller													
	Chiller													
COOLING TOWER			Date needed by: _____			Include: certified efficiencies								
	Cooling tower													
	Cooling tower													
ROOFTOP & MISC. HVAC			Date needed by: _____			Include: fan curves w/ operating point								
	RTU													
	RTU													
	AHU													
	AHU													
	AHU													
	Computer AC													
	Split systems													
	Unit heaters													

Equip. Tag	Equipment Description	Spec Section	Cut Sheets & Perform. Data [b]	Product Description Literature	Installation Guide & Shipped Data [c]	Start-up Guide & Checkout Plan	Any Req'd Test Plans [a]	O&M Booklet or Data	Warranty & Any Service Contract	Control Drawings & Points List	Cntrl. Sequences and Schedules	Design Intent & Basis of Design	Start-up Reports	Certifications (pressure, leaks, gas, gov't inspec.,	Redlines & As-builts
GAS WATER HEATERS			Date needed by:		Include: certified efficiencies										
	DHW heater						--								
	DHW heater						--								
EXHAUST FANS			Date needed by:		Include: fan curves w/ operating point										
							--								
							--								
							--								
							--								
							--								
							--								
							--								
							--								
AIR TERMINAL UNITS			Date needed by:												
							--							--	
							--							--	
							--							--	
BLDG AUTOMATION SYS			Date needed by:		Hard copy of program and setups										
	Control system														
	Valves, dampers														
	Sensors														
TEST & BALANCE WORK			Date needed by:												
	Floors TAB		--	--	--		--	--		--	--	--	--	--	
	Floors TAB		--	--	--		--	--		--	--	--	--	--	
PIPING SYSTEMS			Date needed by:												
	Domestic piping		--	--	--	--	--	--	--	--	--		--		
	Domestic clean/flush							--	--	--	--	--			--
	HW piping		--	--	--	--	--	--	--	--	--		--		
	HW clean / flush		--	--	--			--	--	--	--	--			--
	HW treatment									--	--	--			--
	CHW piping		--	--	--	--	--	--	--	--	--		--		
	CHW clean / flush		--	--	--			--	--	--	--	--			--
	CHW treatment									--	--	--			--

Equip. Tag	Equipment Description	Spec Section	Cut Sheets & Perform. Data [b]	Product Description Literature	Installation Guide & Shipped Data [c]	Start-up Guide & Checkout Plan	Any Req'd Test Plans [a]	O&M Booklet or Data	Warranty & Any Service Contract	Control Drawings & Points List	Cntrl. Sequences and Schedules	Design Intent & Basis of Design	Start-up Reports	Certifications (pressure, leaks, gas, gov't inspec.,	Redlines & As-builts
	CD piping		—	—	—	—	—	—	—	—	—	—	—		
	CD clean / flush		—	—	—			—	—	—	—	—			—
	CD treatment									—	—	—			—
	F. Sprinkler piping		—	—	—	—	—	—	—	—	—	—	—		
	F. S. clean / flush		—	—	—			—	—	—	—	—			—
	F.S. treatment									—	—	—			—
LIGHTING CONTROLS Date needed by: _____															
	Daylighting controls						—							—	
	Occup. sensors						—							—	
	Ltg. sweeps						—							—	
	Ext. lighting cntrls						—							—	
EMERG. POWER SYSTEM Date needed by: _____															
	Generator						—								
	ATS						—								
	UPS						—								
FIRE AND SMOKE ALARM Date needed by: _____															
	FA System														
	Fire / smoke dampers					—	—							—	
	Sys. response matrix		—	—	—	—	—	—	—	—			—	—	
	Fire marshal test		—	—	—	—	—	—	—	—	—	—	—		
MEDICAL GAS SYSTEMS Date needed by: _____															
	Suction														
	O2														
	NO2														
	Piping														

[a] Functional test plans or procedures required in the specifications to be submitted by the contractor.

[b] Plan Tag, Model and Features used on this project must be clearly marked.

[c] This includes the following: a) Installation guide found in the std. O&M booklet or as a separate sheet. b) All installation and O&M data shipped inside the pieces of equipment. c) The actual startup and checkout field record sheets used by the technician, not the generic one found with the installation guide. Additionally, any mfr. engineering bulletins applicable to this equipment shall be included.

[d] Enter a check or date in the left side of the cell when received and an X or date in right side when approved.

COMMISSIONING TEST OR DOCUMENT APPROVAL

Project: _____

☐ Completed Functional Test Approval

Equipment Name: _____

Equipment Tag: _____

Functional Test Description: _____
_____☐ Document Review

Document Name and ID: _____

Review Description: _____

The test(s) of the above equipment or the review of the referenced document(s) have been completed and performance of the component, system or documents complies with the acceptance criteria in the testing or document requirements of the Specifications and Contract Documents, subject to the changes being made as listed below or on an attached sheet.

____ Sheets attached

A copy of the completed test or document review is attached. (Y/N) _____

Commissioning Agent Approval:_____
Commissioning Agent_____
DateConstruction Manager Approval:

The test or review results relating to the above equipment has been reviewed and approved as complying with the contract documents.

Construction Manager_____
DateExclusions:

COMMISSIONING PREFUNCTIONAL CHECK LIST and START-UP SUBMITTAL / APPROVAL

Project: _____

SUBMITTAL NO: _____

☐ New ☐ Resubmittal

Cx Section No: _____

From (initially): _____

To: _____

Equipment or System Tag and Name: _____
_____Included:

____ Prefunctional checklist form

____ Startup and Initial Checkout: ____ Documentation format, ____ Execution Plan

Submissions / Returns

	Transmittal of blanks	Transmittal of blanks	Return of completed forms	Submission of completed forms	Submission of completed forms
Path	To (_ CM, _ GC): _____ from CA: _____	To (sub): _____ from (_ CM, _ GC, _ CA): _____	To (_ CM, _ GC, _ CA): _____ from (sub): _____	To (_ CA, _ A/E, _ Owner) _____ from (_ CM, _ GC, _ CA): _____	To (_ CA, _ A/E, _ Owner, _ CM, _ GC) _____ from (_ CM, _ GC, _ CA): _____
Comments by Submitter	Fill in the "Contr." column with the responsible party. Copy and distribute to all involved contractors. ☐ Notes attached	Execute checklists per directions and return to: _____ ☐ Notes attached	This checklist ____ and startup report has been executed successfully per the contract documents. ☐ Notes attached	This completed checklist ____ and startup report has been reviewed. ☐ Notes attached	This completed checklist ____ and startup report has been reviewed. ☐ Notes attached
Copies					
Submitter Signature					
Title					
Date					
Code	-----				

Submitting Codes: Sb = Submitted as documentation of a completed checklist and/or startup report.

A = Approved as complying with the contract documents.

NC = Note Corrections. Approved, but need to resubmit for the record, after correcting.

NA = Not Acceptable. Resubmittal required for review.

Abbreviations: CA = commissioning agent/authority, CM = construction manager, GC = general contractor's rep.,
A/E = architect or engineer of record, Sub = responsible subcontractor or vendor.

COMMISSIONING TRANSMITTAL

Project: _____

Date: _____

TRANSMITTAL NO: Cx-_____

FROM: _____

_____**TO:** _____

_____**DESCRIPTION:**_____

_____**PURPOSE:**☐ For your retention and use (no comments or approval necessary)☐ For your approval: _____
_____☐ For your review and comments: _____

Respond by: _____

☐ Do not return this copyCopied to: _____

COMMISSIONING REQUEST FOR INFORMATION

Project: _____

RFI NO: Cx-_____

Date: _____

From: _____

_____**To:** _____

_____**RE:** _____**Description:**

This Information Is Needed For The Following Reasons:

- ☐ In order to clarify an area of control, so sequences of operation can be finished.
- ☐ In order to develop prefunctional and startup checklists.
- ☒ In order to develop functional performance test procedures.
- ☐ In order for functional testing to proceed as scheduled.
- ☐ In order to assist in trouble-shooting a functional problem.
- ☐ To fulfill other contracted commissioning responsibilities.

Respond By: _____**Copied To:** _____

COMMISSIONING MEMORANDUM

Project: _____

Date: _____

RE: _____

From: _____

_____To: _____

_____**Discussion:**

Purpose:☐ For your retention and use (no comments or approval necessary)☐ For your review and comments: _____

_____☐ For your approval of the conclusions: _____

Respond by: _____

☐ Do not return this copyCopied to: _____

SEQUENCES OF OPERATION AND FUNCTIONAL TEST PROCEDURES SUBMITTAL

Project: _____ SUBMITTAL NO: _____

☐ New ☐ Resubmittal

From (initially): _____ To (initially): _____

Equipment or System Tag and Name: _____

Included:

- ☐ Sequences of Operation (enlarged from original control drawings and specification documents)
☐ Functional test procedures and forms

Submissions / Returns

The following checked individuals will receive these documents for review and/or approval:

Party	For review & comment only	For review & approval	For record only
General Contractor	_____	_____	_____
Mechanical Contractor	_____	_____	_____
Electrical Contractor	_____	_____	_____
Controls Contractor	_____	_____	_____
Construction Manager	_____	_____	_____
Owner's Representative	_____	_____	_____

Path	To: _____ From: _____	To: _____ From: _____	To: _____ From: _____	To: _____ From: _____	To: _____ From: _____
Comments by Submitter	See Key (1) ☐ Notes attached	See Key (1) ☐ Notes attached	See Key (1) ☐ Notes attached	See Key (1) ☐ Notes attached	See Key (1) ☐ Notes attached
Copies					
Submitter Signature					
Title					
Date					
ReviewCode					

Key: (1) Review and comment on the sequences and/or test procedures as to their compliance with the specs.

Check tests for personnel safety and to keep equip. warranty in force.

Review Codes: AM = Approved by mechanical contractor (or electrical contractor) as complying with the contract documents. Tests will not void warranty or damage equipment and do not present unsafe conditions for personnel.

AC = Approved by controls contractor as complying with the contract documents.

AE = Approved by the design engineer as complying with the contract documents.

NC = Note Corrections. Approved, but need to resubmit for the record, after correcting.

NA = Not Acceptable. Resubmittal required for review.

Abbreviations: CA = commissioning agent/authority, CM = construction manager, GC = general contractor's rep., A/E = architect or engineer of record, Sub = responsible subcontractor or vendor.

COMMISSIONING PROGRESS REPORT

Project: _____ Date: _____ Prepared by: _____

Reporting Period: _____ Report #: _____

Commissioning tasks worked on since last report and general progress:

Areas where schedule is not being met: _____

Recommended actions: _____

Requested schedule adjustments: _____

Next steps: _____

Other comments (include general comments and field notes): _____

Non-Compliance Report attached. (Y/N) _____

Issues Log Attached. (Y/N) _____

Misc. comment sheets attached. (Y/N) _____

Commissioning Agent

PROJECT TRAINING AND ORIENTATION PROCEDURE

Owner training and orientation on equipment and systems provided by the Contractor is accomplished in three general steps using three forms.

1. Overall Plan. After reviewing the specifications, the Owner and Commissioning Agent (CA) fill out a table listing all the equipment that will have training or orientation provided for, on Form C-5a, *Project Training Plan—General Scope and Responsible Parties*. This form lists, among other things, the trainee type and number, rigor of desired training by the Owner, the primary responsible subcontractor, the trainer's company and columns for tracking training agendas. The Commissioning agent provides this form to the Contractor for reference.
2. Specific Training Agendas. For each piece of equipment or system being trained on, the Owner and CA fill out Section 1 of the *Training and Orientation Agenda*, Form C-5b. This section includes some of the information from Form C-5a regarding the scope of training and the intended audience, for reference by the trainer in developing their training agenda. The CA develops a plan for including in the training session contractors / trainers from different disciplines, when appropriate, by listing their company names in Section 2 of the form. In particular, the controls contractor will provide brief training on controls, in the same session with the mechanical training for equipment controlled by the building automation system.

This form is then submitted to the Contractor who has their trainer fill out the rest of Section 2 and 3 of the form (Form C-5b), describing the subjects covered, duration of each subject and the methods that will be used in the training, along with the name and qualifications of the trainer(s). The trainer returns this form to the Contractor, who submits it to the Owner and CA. The Owner and CA review the agenda; make comments; approve subject to the comments; and submit back to the Contractor. The Contractor provides the approved agenda to the trainer to use during the training. The trainer provides a copy of the agenda to each trainee.

3. Training Record. For each piece of equipment, prior to training, the Contractor provides to their trainer(s) Form C-5c, *Training and Orientation Record*. On this form, the trainer documents each training session (duration and general subjects covered). The trainer signs for the session and obtains the signature of each trainee. The trainer also checks off subjects covered on their Agenda (Form C-5b). When the training is complete, the Contractor provides a copy of the *Training and Orientation Record*, Form C-5c, and the trainer's Agenda, Form C-5b. The Owner and CA review C-5c and make final approval by signing it. The CA may witness any of the training sessions.

OVERALL STAFF TRAINING AND ORIENTATION PLAN

Project: _____ Date: _____ Prepared by: _____

(To be filled out by the Commissioning Agent in consultation with the Owner)

Equipment / System	Spec Section	Total Hours (if spec'd)	Scope Code ⁵	Trainee Type ⁶ (list no. of ea.)	Primary Responsible Contractor	Trainers' Company	Agenda Recv'd?	Planned Training Date(s)
Mechanical / HVAC								
Electrical								

Equipment / System	Spec Section	Total Hours (if spec'd)	Scope Code ⁵	Trainee Type ⁶ (list no. of ea.)	Primary Responsible Contractor	Trainers' Company	Agenda Recv'd?	Planned Training Date(s)
Re-Commissioning¹								
Architect²								
Mechanical Designer³								
Electrical Designer⁴								

¹**Recommissioning.** The commissioning agent will provide instruction on the use of blank functional test forms for periodic recommissioning of equipment and systems, per the specification.

²**Architect.** The architect will provide a general overview of the facility, its use, special features, tenant and public considerations, etc.

³**Mechanical Design Engineer.** The mechanical designer will provide an overview of the major systems and equipment in the facility, including for each system: the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.

⁴**Electrical Design Engineer.** The electrical designer will provide an overview of the major electrical systems and equipment in the facility, particularly the lighting control systems, fire alarm, security and emergency power, focusing on the design intent, why the system was chosen, an overview of its operation, and interactions with other systems, any special areas to be aware of, issues regarding future expansion and remodeling, etc.

⁵**General Scope Codes** (refer to the specifications and to the specific equipment Training Agenda for additional details)

- A Provide an *overview* of the purpose and operation of this equipment, including required interactions of trainees with the equipment.
- B At an *intermediate level*, provide technical information regarding the purpose, operation and maintenance of this equipment, expecting that serious malfunctions will be addressed by factory reps.
- C At a *very technical level*, provide information regarding the purpose, operation, troubleshooting and maintenance of this equipment, expecting that almost all operation, service and repair will be provided by the trainees.

⁶**Trainee Types**

FM = facility manager, FE = facility engineer and assistants, FT = facility technician / maintenance,
PM = project manager, T = tenants, O = other

*OSCI = Owner supplied, contractor installed

TRAINING AND ORIENTATION AGENDA

Project: _____

Date: _____

Equipment / System: _____

Spec Section: _____

Section 1. Audience and General Scope [Owner and Commissioning Agent fill out this section and transmit entire form to responsible contractors. Attach training specification section.]

Intended audience type (enter number of staff): ____ facility manager, ____ facility engineer, ____ facility technician, ____ project manager, ____ tenant, ____ other: _____

General objectives and scope of training: (check all that apply)

- ____ A. Provide an overview of the purpose and operation of this equipment, including required interactions of trainees with the equipment.
- ____ B. Provide technical information regarding the purpose, operation and maintenance of this equipment at an intermediate level, expecting that serious malfunctions will be addressed by factory reps.
- ____ C. Provide technical information regarding the purpose, operation, troubleshooting and maintenance of this equipment at a very detailed level, expecting that almost all operation, service and repair will be provided by the trainees.

Section 2. Instructors [Commissioning agent fills in Company. Trainer fills out the balance, prior to training.]

ID	Trainer	Company	Position / Qualifications
1)	_____	_____	_____
2)	_____	_____	_____
3)	_____	_____	_____

Section 3. Agenda [The responsible contractors have their trainers fill out this section and submit to Owner and Commissioning Agent for review and approval prior to conducting training.]

Location: ____ site _____ Date _____
 ____ classroom (location) _____, Date _____

Agenda of general subjects covered

(√ all that will be covered)

(√ when completed)

Duration (min.)	Instructor (ID)	Completed (√)
--------------------	--------------------	------------------

____ General purpose of this system or equipment (design intent)	_____	_____
____ Review of control drawings and schematics (have copies for attendees)	_____	_____
____ Startup, loading, normal operation, unloading, shutdown, unoccupied operation, seasonal changeover, etc., as applicable	_____	_____
____ Integral controls (packaged): programming, troubleshooting, alarms, manual operation	_____	_____
____ Building automation controls (BAS): programming, troubleshooting, alarms, manual operation, interface with integral controls	_____	_____
____ Interactions with other systems, operation during power outage and fire	_____	_____
____ Relevant health and safety issues and concerns and special safety features	_____	_____

<u>Energy conserving operation and strategies</u>	_____	_____	_____
<u>Any special issues to maintain warranty</u>	_____	_____	_____
<u>Common troubleshooting issues and methods, control system warnings and error messages, including using the control system for diagnostics</u>	_____	_____	_____
<u>Special requirements of tenants for this equipment's function</u>	_____	_____	_____
<u>Service, maintenance, and preventative maintenance (sources, spare parts inventory, special tools, etc.)</u>	_____	_____	_____
<u>Question and answer period</u>	_____	_____	_____

<u>Other subjects covered, specific to the equipment:</u>	<u>Duration</u>	<u>Instructor</u>	<u>Completed</u>
--	------------------------	--------------------------	-------------------------

_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
Total duration of training (hrs) -----> <div style="border: 1px solid black; display: inline-block; width: 60px; height: 20px; vertical-align: middle;"></div>			

Training methods that will be included (clarify as needed): (Trainer checks all that apply)

✓ use of the O&M manuals, illustrating where the verbal training information is found in writing

✓ each attendee will be provided: 1) the control drawing schematic and sequence of operations;
2) a copy of this agenda.

✓ discussion/lecture at site _____

✓ site demonstration of equipment operation _____

_____ written handouts _____

_____ manufacturer training manuals _____

_____ classroom lecture _____

_____ classroom hands-on equipment _____

_____ video presentation _____

✓ question and answer period _____

Section 4. Approvals and Use [Once the Agenda has been filled out by the Trainer, the Owner and Commissioning Agent review, make edits, sign and return to Contractor who provides to the Trainer for use during training. Copies of Agenda shall be provided to trainees.]

This *plan* has been approved by the following individuals, subject to the additions and clarifications noted in the left columns marked "add." (This is not an approval of training completion.)

Owner's Representative _____

Date _____

Commissioning Agent _____

Date _____

STAFF TRAINING AND ORIENTATION RECORD

Project: _____ Date: _____ Prepared by: _____

System or Equipment: _____

Trainee Signature ² and Position	Total Req'd Hrs ¹	Hrs Done	Training Date	General Topics Covered	Trainer Signature and Company	CA Initials/ Note ID
1.						
2.						
3.						
4.						

¹The hours of required training have been filled out from the *Specifications*. Refer to the *Specifications* for additional details regarding the training requirements.

²Trainee signs after the training session is completed.

Notes attached. (Y/N) _____

Final Approval of Training Completion
According to the Contract Documents:

Owner's Representative

Date

Commissioning Agent

Date

COMMISSIONING CORRECTIVE ACTION REPORT

Project: _____

ID: _____

Equipment: _____

Equipment ID: _____

Identified from: Test, Review, Discussion, ☐ Site visit _____
Date

The above equipment has been observed, tested or the performance report reviewed and was found to not comply with the contract documents.

Deficiencies or Issues and Effects:

Corrective Action: ☐ Required ☐ Recommended.

For testing to proceed in a timely manner, it is imperative that the required corrective action be completed by: _____
Date or Event

Commissioning Agent	Date	Owner's Representative	Date
---------------------	------	------------------------	------

Forwarded to the following parties on _____ for corrective action:
Date

Attachments (Y / N) _____

Fill in the following section and return entire form to commissioning agent when corrected.

Statement of Correction

The above deficiencies have been corrected with the following actions:

Signature	Firm	Date
-----------	------	------

COMMISSIONING PROGRESS RECORD

Project: _____

SUCont = Contractor doing startup Incl. Plan	PC_Del = PC delivered to Sub (date)	SUPPlan = Start-Up Plan
FTCont = Contractor doing functional tests	SUSchd'd = StartUp scheduled date	SUP Rep = Start-Up Report Incl. PC
Doc's = Requested documentation received	FTSchd'd = Functional test scheduled date	TAB = TAB completed for this equip.
CxSect = Assigned in commissioning section ID	FT_OK'd = F. Test form OK'd by Installer	FT = Functional Test execution
SpecSect = Std. Specification section	PC = Prefunctional checklist	Training = Training of facility staff
[1] Approvals officially documented on Form C-3.	DocRev = Documentation submittal review	O&M Doc = Review of docum. in O&M's

Equipment or System		Type	Form / Doc. ID #	Approval Dates [1]			
				Cx Agent	Owner's Rep	A/E	Fail Date
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUPPlan					
Installer _____	SpecSect _____	SUPRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'd _____	FT					
FTCont _____	FTSchd'd _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					

Equipment or System		Type	Form / Doc. ID #	Approval Dates [1]			
				Cx Agent	Owner's Rep	A/E	Fall Date
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					
Name _____		DocRev					
Plan ID _____	CxSect _____	SUpPlan					
Installer _____	SpecSect _____	SUpRep					
SUCont _____	PC_Del _____	TAB					
FTCont _____	SUSchd'Id _____	FT					
FTCont _____	FTSchd'Id _____	Training					
Doc's _____	FTOK'd _____	O&M Doc					

PLAN AND DOCUMENTING REQUIREMENTS FOR STARTUP AND INITIAL CHECKOUT

Project: _____ Date: _____ Prepared by: _____

Primary Equipment and Tag: _____

Component or Related Equipment Included: _____

The purpose of documenting the startup and checkout process is to ensure to the Owner that all recommended startup and initial checkout procedures are completed and that a written record of the work is generated.

PLAN and PROCEDURES:

1. The prefunctional checklists provided by _____ should be filled out and signed for the above primary and related equipment.
2. The attached pages have been copied from the _____ installation manuals submitted to _____. They have had paragraphs and sections identified and marked with a signature lines in the margins. Separately for each piece of equipment, during startup and checkout, the technician should check and date each check box and initial and date each line made for that purpose, signifying completion of the task. All readings and settings shall be recorded, not just checked. Provide clear, written notes at the bottom, margin or back-side of each page, as necessary. Written notes shall be provided for why an item was not done or does not apply. A signature and date of the startup technician shall be provided at the end of the startup and checkout documents.
3. This list of procedures does not constitute a recommendation of the full installation and startup procedures or release the installer from following all factory recommendations, the specifications, applicable codes and good practice. Other pages applicable to this piece of equipment in the installation manual or any other procedures completed should be added.
4. Other startup record forms normally used should also be filled out and submitted.

All documentation should be submitted to _____ upon completion and is required prior to the execution of functional testing.

Project _____

DETAILED COMMISSIONING SCHEDULE

Last Edit Date_____

[illegible]

[illegible]

Task / Activity		Week ->																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
Manual Test Execution																												
9 Documentation Verification																												
10 Training Verification																												
11 Final Cx Report																												
12 Seasonal testing																												

1 of 4

Ending

[illegible]

[illegible]

Task / Activity	Ending																											
		Week -->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
9 O&M Documentation Verification																												
10 Training and Verification																												
System																												
System																												
System																												
11 Final Cx Report																												
12 Seasonal testing																												
Cooling system																												
Heating system																												
	Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	

[illegible]

1

PHASING OF COMMISSIONING TESTING

Project: _____ **Date:** _____ **Prepared by:** _____

[illegible]

Sample Phasing of Commissioning Testing

Main Equipment or System	Group of Equipment to Test Together	
	Startup and Initial Checkout (Pre-functional Work)	Functional Performance Testing—In-depth Checkout
AHU's	AHU 1-4	AHU 1-5
	AHU 5	—
	AHU 6-8	AHU 6-8
Terminals	Floors 1-3	All floors (sampling)
	Floors 4-9	
TAB, air	na	All floors (sampling)
	na	—

OWNER-CONTRACTED OR OWNER-CONDUCTED TESTS OF COMMISSIONED EQUIPMENT

Project: _____ Date: _____ Prepared by: _____

Equipment	Test Description	Spec Section	Rigor	Needs Additional Testing?

FACILITY STAFF PARTICIPATION IN COMMISSIONING

Project: _____ Date: _____ Prepared by: _____

Activity	Staff ID #'s

See staff ID below.

Staff Data (Name, title, telephone, etc.)

Staff 1: _____

Staff 2: _____

Staff 3: _____

Staff 4: _____

Staff 5: _____

Staff 6: _____

Staff 7: _____

Example Functional Testing Scope Outline

Project: _____ Date: _____ Prepared by: _____

Last Edit Date _____

System or Equipment	Equipment or Component Tested	General Description of Modes and Functions to Test	Testing Method (Manual, Trend-log, Data-logging)	Sampling Strategy (list applicable equip.)	Who Executes Test	Seasonal Test Req'd (list applicable equip. & modes)
Chilled Water System	Chillers, primary and secondary CHW pumps, CDW pumps, cooling tower (CT), VFD, controls	All sequences of chiller and cooling tower and related pumps (startup, shutdown, load changes, resets, lead lag action, alarms, lockouts), VFD control, temporary power, chiller capacity and efficiency, CT capacity and efficiency, part load curves with manuf.	Mostly M, with some T and some D	Test all including standby equip., except capacity & efficiency test of chiller & CT need only be done on 1 piece, even if identical	Mech. leads with help from: Cntrl	Chiller test must be done in summer, CT in summer and <u>✓</u> winter
Hot Water Heating System	Boiler, steam converter, pumps, controls	All sequences of hot water systems and related pumps (startup, shutdown, load changes, resets, lead lag action, alarms, lockouts), VFD control, temporary power, efficiency, venting	Mostly M, with some T and some D	Test all including standby equip., except effc. test only one boiler, even if identical	Mech. leads with help from: Cntrl	Must test in winter
Air handling system	AHU, supply, return and exhaust fans, coils, coil pumps, valves, dampers, VFD, controls	All sequences of fans and related components (startup, shutdown, setup, unoccupied conditions, load changes, resets, alarms, lockouts), VFD control, operation of all dampers in all modes, temporary power, coil capacity, coil effc., OSA control, bldg. pressure,	Mostly M, with some T and some D	Test all	Cntrl leads with help from Mech.	Must test in <u>✓</u> sum'r <u>✓</u> winter

System or Equipment	Equipment or Component Tested	General Description of Modes and Functions to Test	Testing Method (Manual, Trend-log, Data-logging)	Sampling Strategy (list applicable equip.)	Who Executes Test	Seasonal Test Req'd (list applicable equip. & modes)
Air handling system	Terminal units	Verify damper and fan sequences during heating, cooling, debands, occupied, unoccupied, verify flow	M	Test 10% of identical units (see Specs)	Mech. leads with help from Cntrl	No
Computer Room AC	AC unit, humidifier, controls	All sequences in all modes (normal, deadband, unoccupied, etc.), humidity and reheat functions, backup interlock with primary cooling, temporary power operation	M	Test all	Mech.	No
Spot HVAC Units	Unit heaters, controls	All sequences, occupied, unoccupied, lockouts, simultaneous heating /cooling issues	M	Test 10% of identicals and at least 5	Mech.	No, if htg & cooling condition is simulated
Spot HVAC Units	Spot coolers, controls	All sequences, occupied, unoccupied, lockouts, simultaneous heating /cooling issues	M	Test 10% of identicals and at least 5	Mech.	No, if htg & cooling condition is simulated
Specialty Fans	Stairwell pressurization fans, controls	Tested by fire officials				
Specialty Fans	Central exhaust fans, controls	Occupied, unoccupied, local controls, overrides, schedules, central controls	M	Test all	Mech.	No
Specialty Fans	Fume hoods	Capacity, varying differential pressures, interlocks, safeties	M	Test all	TAB contr.	No, if tested with full and min. OSA

System or Equipment	Equipment or Component Tested	General Description of Modes and Functions to Test	Testing Method (Manual, Trend-log, Data-logging)	Sampling Strategy (list applicable equip.)	Who Executes Test	Seasonal Test Req'd (list applicable equip. & modes)
Energy Management Control System	Schedules, sequences, lockouts, alarms, interlocks, control strategies, trending	All sequences of control for HVAC equipment and lighting controls,	M and T with some D	Test all controlled equipment	Cntrl	Yes, see Specs
Packaged HVAC	AHU, supply, return and exhaust fans, compressor, condensers, coils, valves, dampers, heating elements, VFD, controls	All sequences of fans and related components (startup, shutdown, setup, unoccupied conditions, load changes, resets, alarms, lockouts), VFD control, operation of all dampers in all modes, temporary power, OSA control, building pressure, reversing valves (HP), compressor and cond. fan staging, heating COP & capacity, cooling EER & capacity	Mostly M with some T and some D	Test 20% of identical units < 20 tons. test 40% of identical units > 20 tons. Test at least 4 of each.	Mech. Lead with help from: Cntrl	No, for units < 20 tons, if simulated condition is used. Yes, for units > 20 tons
Heat Exchanger	Heat exchanger, controls	Sequences, lockouts, safeties	M & T	Test all	Mech.	No
TAB	Air and water TAB work	Primary air and water flows and terminal flows	M	Verify a % of TAB readings (see Specs)	TAB	No
Clean Room Air Flows	Air flows and pressures	All sequences and all possible affecting conditions in bldg., varying differential pressures, interlocks, alarms	M and some T	Test all	TAB	No, if tested with full & min. OSA & full htg. & cooling

System or Equipment	Equipment or Component Tested	General Description of Modes and Functions to Test	Testing Method (Manual, Trend-log, Data-logging)	Sampling Strategy (list applicable equip.)	Who Executes Test	Seasonal Test Req'd (list applicable equip. & modes)
Service Hot Water	Boiler, heaters, pumps, controls	Boiler or heater sequences, controls & pump schedules	M	Yes (see Specs)	Mech.	No
Lighting Controls	Sweep, occupancy sensors, daylighting	Occupied, unoccupied, overrides, sweep, varying daylight, occupancy, as applicable, occupant use	M	Test all	Elec. leads Cntrls helps	No

COMMISSIONING FORMAL WRITTEN WORK PRODUCTS

Project _____

Last Edit Date _____

Product	Created By	Product Description and Form	Due Date	Received By	Approved By	Product Assigned In
Scoping Mtg Minutes	CA	Minutes and notes of the scoping meeting	< 1 week after meeting	All Cx team	na	Cx Plan 5.1 Specs 17100, 1.5
Final Cx Plan	CA	Final Cx plan for const. phase (edited version of Draft plan of bid documents)	1-2 weeks after Cx scoping mtg.	All Cx team	CM	Cx Plan 5.2, Specs 17100, Pt 1.5
Cx Schedule	CA	Initial summary schedule (Table 7-1) and detailed version (Form C-10)	Summary schedule: 1wk after scoping	All Cx team	CM	Cx Plan 7.1
Equipment submittals	All Subs	Detailed data on all Cx'd equip.	during normal submittals	CA	CA (for Cx req'r.)	Cx Plan 5.7, Specs 17100, Pt 3.3, 15995 Pt 3.1
Prefunctional tests and checklists	Specs and CA	List by equipment of prefunctional checklists and prefunctional tests (Specs 15998)	During normal submittals	Subs	CA	Cx Plan 5.8.1, Specs 17100 Pt 3.4; 15995 Pt 3.2
Start-up and initial checkout plans	All Subs and CA	Specific listing of procedures for combining CA prefunctional checklists with Sub's startup and checkout.	2-weeks before execution	CA	CA	Cx Plan 5.8.1, Specs 17100 Pt 3.4; 15995 Pt 3.2
Start-up and initial checkout reports	All Subs	Filled out prefunctional checklists, tests, startup and initial checkout	1-week after startup completion	CA + normal others; O&M's	CA recommend to CM	Cx Plan 5.8.2, Specs 17100, Pt 3.4
Controls Contractor Initial Check-out Plan	Controls Contr.	Complete step-by-step plan on checkout and calibration procedures, including forms for documenting	3 weeks before beginning checkout	CA	CA recommend to CM	Cx Plan 5.8.7, Specs 15995
TAB plan and approach	TAB	Outline of TAB plan, approach and schedule (file: tabplan.c03)	< 6weeks before TAB	CA, CM; Cntrls contr.	CA; CM	Cx Plan 5.8.6, Specs 15995 1.2
TAB progress reports	TAB	List of discrepancies, interpretations needed, tests completed	Twice a week	CA and CM	none	Cx Plan 5.8.6, Specs 15995 Pt 1.2
Draft TAB report	TAB	Draft TAB report with method and results	< 2weeks after TAB completion	CA + normal others	CA (for Cx req'r.)	Cx Plan 5.7.2, Specs 15995 Pt 1.2
Final TAB report	TAB	Draft TAB report with method and results	< 2 weeks after TAB completion	CA + normal others; O&M's	CA (for Cx req'r.)	Cx Plan 5.7.2, Specs 15995 Pt 12; 3.6
Change orders	GC; CM	Change orders that affect Cx'd equipment	<1-week after approved	CA + others	na	Cx Plan 5.7.2, Specs 17100 1.5
Issues Log	CA	Record / track of all issues and deficiencies (Form C-1)	ongoing	CM	na	Cx Plan 5.6

Product	Created By	Product Description and Form	Due Date	Received By	Approved By	Product Assigned In
Non-Compliance /Deficiency reports	CA	List of deficiencies and non-compliance with Contract Docs identified during Cx (Form C-6)	Issued within 3 days of identifying	CM from CA and by Subs from CM or CA	CM	Cx Plan 5.8.4; 5.10.2, Specs 17100 Pt 1.5, 3.4; 3.7
Cx'g Progress Record	CA	Record / track of all submittals, checklists, tests, etc. (Form C-7)	ongoing	CM	na	Cx Plan 5.6
Cx progress reports	CA	Gives scheduling needs and update, deficiency report, Cx progress (Form C-4)	Weekly to Monthly (see 5.5)	CM or PM	na	Cx Plan 5.6, Specs 17100, Pt 1.5
Owner-contracted functional test forms	Subs/ vendor	Full description of test procedures in "form" format	>4-weeks before test	CA	CA	Cx Plan 5.9.2, Specs 17100 Pt 1.5; 3.3
Functional test forms	CA	Full description of test procedures in "form" format (Specs 15999; 16999)	>4-weeks before test	CM, Subs, O&Ms; ___A/E	CM and Sub; ___A/E	Cx Plan 5.9.2, Specs 17100 Pt 1.5; 3.6, 15997
Filled out functional test forms	CA	Recorded documentation of the test on the form	With final report	CM, O&Ms; ___A/E	CM	Cx Plan 5.9, Specs 17100 Pt 1.5; 3.6
Functional test final approvals	CA	List of test number, and descript., date of test, approval signatures of CA and CM (Form C-3)	Within 4 days of successful completion of test	CM	CM	Cx Plan 5.10, Specs 17100 Pt 1.5; 3..7
O&M manuals (normal)	GC and Subs	Documentation of design, equipment, operations and maintenance, as-builts, etc.	Before substantial completion	CA reviews on-site	CA (for Cx req'r)	Cx Plan 5.11, Specs 17100 Pt 3.8, 15995 Pt 3.6
Training plan	Subs	Topics and methods (Forms C-5a; 5b)	2 weeks before training	CA; CM	CA; CM	Cx Plan 5.12, Specs 17100 Pt 3.9, 15995 Pt 3.7
Training completion form	CA	List of trainees, completed hrs and topics and approvals (Form C-5c)	<2 weeks after training completion	CA	CA recommend to CM	Cx Plan 5.12, Specs 17100 Pt 1.5, 3.9
Final Cx report	CA	4-6 page summary report with important findings, etc.	Draft within 60 days of substantial completion	CM	CM	Cx Plan 6.1 Specs 17100 Pt 1.5
Deferred testing reports	CA	Documentation of seasonal and deferred tests	Within 2 weeks of test	CM & PM	CM & PM	Cx Plan 5.13, Specs 17100 Pt 3.10

Form C-17. Sample Commissioning Record Notebook Format

I-1 thru I-6 and 01 - 14 are major tabs (colored). Sections A-C under major tabs are sub-tabs (clear). Major tabs may fill an entire binder as necessary.

Three Clear Tabs Under Each Major System [1] (With contents listed on cover sheet)

I-1	CORRESPONDENCE
I-2	COMMISSIONING PLAN
I-3	COMMISSIONING SCHEDULE
I-4	MEETING MINUTES & PROGRESS REPORTS
I-5	PROGRESS RECORD
I-6	ISSUES LOG
01	CHILLER SYSTEM
02	HW SYSTEM
03	AIR HANDLERS
04	PACKAGED AC UNITS
05	TERMINAL UNITS

A- DESIGN

- *Design narrative
- *Design criteria
- *Sequence of operation
- *Approvals of above

B- PREFUNCTIONALS

- Sub-divider sheet for each type of equipment, (pumps, chillers, CT, etc.)
- *Startup plan, report & checklists
- *Approvals & corrections of above
- *Blank prefunctional checklists

C- FUNCTIONAL TESTS

- *Filled out tests
- *Trending & analysis
- *Approvals & corrections of above
- *Training plan, record & approvals
- *Blank test forms

5a FLOOR 1

5b FLOOR 2

OR Zone 1, Zone 2....etc.

Major Tabs Continued:

- 06 Computer room AC units
- 07 Unit heaters or AC spot coolers
- 08 Heat exchangers
- 09 Service water system
- 10 Test and balance (TAB)
- 11 Building automation system (controls)
- 12 Specialty fans
- 13 Fume hoods
- 14 Split AC / HP
- 15 Lighting controls
- 16 Emergency power
- 17 UPS
- 18 Fire alarm / protection
- 19 Misc.

[1] For smaller projects, colored separator sheets may be used in place of sub-tabs.

O&M Manuals

The Record Notebook is edited before becoming a part of the O&M manuals. Include:

- * Final report
- * Commissioning Plan
- * Issues log
- * Progress record
- * All equipment-specific data from the record book

Part IV

APPENDIX 2

Document and Test Development Flow Charts and Submittal Maps

- Chart 1 Startup and Initial Checkout Form Development
- Chart 2 Functional Test Form Development
- Chart 3 Prefunctional Checklist and Startup Report Submittal Map
- Chart 4 Functional Test Submittal Map
- Chart 5 Checklist and Functional Testing Approval Process

Chart 1. Startup and Initial Checkout Form Development

Chart 2. Functional Test Form Development

**Chart 3. Prefunctional Checklist and Startup Report
Submittal Map**

CA = Commissioning Agent
GC = General Contractor
Sub = Subcontractor
Owner = Owner's Rep (construction manager, etc.)

Chart 4. Functional Test Submittal Map

Chart 5. Checkout and Functional Testing Approval Process

(This chart begins with the Checklist or Test already completed.)

Abbreviations

CA = commissioning agent
Rep = owner's representative
Cx = commissioning
GC = general contractor
PC = prefunctional checklist
FT = functional test