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# Part IV

## Model Commissioning Plan --Construction Phase--

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Initially Sponsored (Ver. 2.04) by  
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Version 2.05 Modifications Sponsored by  
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*Version 2.05*

February 1998

Version 2.04 was distributed by PEGI in 1997 and by USDOE in 1998, with USDOE referenced in the footer of each file. Since that version, changes and additions have been made by PEGI without review by USDOE; subsequently in Version 2.05 the reference to USDOE has been removed from the footers. Individual files may have been updated without changing the overall version number. An uptodate history of changes is found in the file *history*....

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# 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

<p><i>Project:</i> _____          _____  <i>GSA Contact:</i> _____  <i>Date:</i> _____</p>	<p style="text-align: center;"><u>Cx Plan Version</u></p> <p>__ Draft 1—Design Phase</p> <p>__ Draft 2—Bid Documents</p> <p>__ Final Cx Plan</p>
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*Plan Approved:* \_\_\_\_\_

Signature	Title	Date
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## 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 authority	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 Do

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 D

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
<b>Owner</b> Project Manager Site Engineer Property Manager _____		
<b>Construction Manager</b> General Site Contact Mechanical		
<b>General Contractor</b> Site Supervisor Site Coordinator		
<b>Commissioning Authority</b>		
<b>Architect</b>		
<b>Mechanical Designer/Eng.</b>		
<b>Electrical Designer/Eng.</b>		
<b>Tenant Representative</b>		
<b>Mechanical Contractor</b> HVAC Site Superv. Piping Contractor Sheet Metal Contractor		
<b>Electrical Contractor</b> Site Supervisor		
<b>TAB Contractor</b>		
<b>Controls Contractor</b> Project Manager Project Engineer		

4.

## Roles and Responsibilities

### 4.1

### Locations of Role Descriptions

[Bid Do

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: *Cx Plan* 5; *Specs* 17100, Pt. 1

CM, PM: *Cx Plan* 5; *Specs* 17100, Pt. 1

Mechanical contractor, TAB, controls contractor, subs and mfr's: *Specs* Div. 1<sup>1</sup>, 15995, 15990, 15997, 16998, 17100

Electrical contractor, subs and mfr's: *Specs* Div. 1<sup>1</sup>, 16995, 16997, 16998, 17100

Commissioning authority: *Specs* Div. 1<sup>1</sup>, 17100, 15 and 16997

A/E: A/E contract, Div. 1<sup>1</sup>, *Specs* 17100

<sup>1</sup>Division 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 Do

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 Do

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.

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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*. This form is used to track the all actions taken on each issue listed, over time until the issue is totally resolved and verified. 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. The CA reviews and approves submissions relative to commissioning issues expressed in the contract documents, not for general contract compliance (which is the A/E's responsibility), unless specifically directed by the owner to do so. 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. CA recommendations are provided to the A/E, owner or CM as directed.

### 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 authority 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 checklisting, 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 startup work will be witnessed by the commissioning authority. Observation of prefunctional checklist execution will be at the discretion of the CA.

<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 authority 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

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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 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. For any given system, prior to performing functional testing, the CA waits until the prefunctional checklist has been submitted with the necessary signatures, confirming that the system is ready for functional testing. 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 and assembly into labeled, indexed and tabbed, three-ring binders and deliver it to the Owner, to be included with the O&M manuals. The correspondence, meeting minutes and progress reports, miscellaneous notes, etc. kept in the Commissioning Record during construction will not be retained into this record and the O&M manuals. The format of the manual follows:

Tab 1	Commissioning Summary Report
Tab 2	Issues Log (log of commissioning findings and resolution)
Tab 3	Commissioning Plan
Tab 4	Commissioning Progress Reports

Tab 5	Submittal Reviews
Tab 6	O&M Manual Reviews
Tab 7	Summary Training Record
Tab 8	Design Record of all systems (Owner Objectives, Design Basis and Design Narratives and Performance Metrics)
Tab 9	Functional Testing Schedule
Tab 10	System / Equipment # 1 (chiller CH-1, air handler AH-3, etc.) Sequence of Operation for Equipment #1 <i>Colored separator sheet</i> Functional Test Record and any approvals (filled out test procedures). Include trend logs if conveniently separated by equipment, otherwise include trend logs and analysis for all equipment in a separate Tab. <i>Colored separator sheet</i> Construction Checklist (filled out) <i>Colored separator sheet</i> Startup Report <i>Colored separator sheet</i> Training Record
Tab 11	System / Equipment / Assembly # 2.....repeat as per System 1
Tab xx	Trend Log Analysis for all systems with table of contents by page number, each graph labeled identifying equipment and issues being illustrated, with page numbers on each graph.

### 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 Authority (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 authority 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 authority 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**

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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**

The summary commissioning report shall include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope and a general description of testing and verification methods. For each piece of commissioned equipment, the report should contain the disposition of the commissioning authority regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas: 1) Installation, including equipment meeting the equipment specifications, 2, Functional performance and efficiency, 3) Equipment O&M manual documentation , and 4) Operator training. All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions, commissioning process changes, etc. shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log, etc. where the deficiency is documented. The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used (manual testing, BAS trend logs, data loggers, etc.) and include observations and conclusions from the testing.

**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**

	<b>Estimated Start</b>	
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<b>Task / Activity</b>	<b>Date</b>	<b>Estimated End Date</b>
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

The following forms are provided electronically, as well as a few hardcopy samples.

<u>Form Number</u>	<u>Description</u>	<u>File Name</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	APROVAL2.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-5d	Building Automation System Training Agenda	BASTRAIN.C5D
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-11a	Commissioning Functional Testing Plan Overview	FTOVRVU.11a
C-11b	Commissioning Functional Testing Status Record	FTSTATUS.11b
C-12	Phasing of Commissioning Testing	PHASES.C12
C-13	Owner-Contracted Tests	OWNRTEST.C13
C-14	Facility Staff Participation in Commissioning	STAFPART.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
C-18	Monitoring and Trending Request Form	TRENDREQ.XLS

<sup>1</sup>Each form in the Appendix has been provided in electronic form, Word 6.0 for Windows 3.1, or Excel 5.0 for Windows 3.1. The filename extension is the form number. There are no version numbers.

## Part IV

### APPENDIX 2

#### *Commissioning Process Overview*

Normal submittals, including sequences of operation and design narratives (by A/E) <sup>1</sup>	<ul style="list-style-type: none"> <li>• A/E and Contractors provide to CA</li> <li>• CA approves for clarity</li> </ul>
O&M documentation (technical O&M materials on commissioned equipment)	<ul style="list-style-type: none"> <li>• Contractors provide to CA before startup in order to write tests (this is in addition to the normal O&amp;Ms to be submitted later)</li> </ul>
Construction Checklists	<ul style="list-style-type: none"> <li>• CA provides lists to Contractors (Controls Contractor (CC) also provides their own)</li> <li>• Contractors fill out</li> <li>• Finished copy submitted to CA</li> <li>• CA approves (and may spot check)</li> </ul>
Start-up Reports	<ul style="list-style-type: none"> <li>• Contractors use their own forms</li> <li>• Contractors fill out</li> <li>• Finished copy submitted to CA</li> <li>• CA approves (and may spot check)</li> </ul>
Functional Test Procedures Forms	<ul style="list-style-type: none"> <li>• CA develops forms and submit to Contractors</li> <li>• Contractors approve for equipment and personnel safety</li> <li>• A/E copied</li> </ul>
Equipment Sequence Checks (controls system) (this is different than calibrations and point-to-point done in Construction Checklists)	<ul style="list-style-type: none"> <li>• CC plans and executes their own</li> <li>• CA may witness and may document</li> </ul>
Functional Test Execution	<ul style="list-style-type: none"> <li>• CA directs and documents</li> <li>• Contractors assist (primarily the CC)</li> <li>• CA approves equipment operation</li> <li>• Finished forms copied to A/E</li> </ul>
Trend Logs	<ul style="list-style-type: none"> <li>• Trending plan submitted by CA to CC</li> <li>• Trending performed by CC</li> <li>• Data prepared by CC in electronic spreadsheet format and submitted to CA</li> <li>• CA views and analyzes data as part of system operation verification and provides a report</li> </ul>
Training Agenda	<ul style="list-style-type: none"> <li>• CA provides forms to Contractors (partially filled out)</li> <li>• Contractors approve for scope, fill out more of the form (hrs, etc.) and submit a copy to the CA</li> <li>• CA approves</li> </ul>
Training Execution	<ul style="list-style-type: none"> <li>• Contractors perform training using the agenda</li> <li>• Contractors have trainees sign in</li> <li>• Finished forms submitted to CA</li> <li>• CA approves (and may witness some training)</li> </ul>
O&M Documentation and As-Builts	<ul style="list-style-type: none"> <li>• Contractors develop and submit to CA (at the same time as the A/E)</li> <li>• CA recommends changes and approves</li> </ul>
Seasonal Functional Testing	<ul style="list-style-type: none"> <li>• CA returns to site to test certain functions</li> <li>• Contractor may or may not be needed to assist depending on facility staff controls abilities</li> </ul>
Near Warranty-End Review	<ul style="list-style-type: none"> <li>• CA meets with facility staff and goes over outstanding issues</li> <li>• Contractor responds to requests for warranty work by Owner or PM</li> </ul>

CA = commissioning authority, CC = controls contractor, PM = project manager

<sup>1</sup>Normal submittals, construction observation and review by A/E and CM are not affected, other than there may be another approving party, the CA.