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USACE / NAVFAC / AFCESA / NASA **UFGS-01 91 00 (July 2006)**

Preparing Activity: NAVFAC

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated 18 July 2006
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07/06

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SECTION 01 91 00

COMMISSIONING
07/06

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NOTE: This guide specification covers the requirements for whole-building commissioning.

NOTE: This specification has NOT been coordinated with Army versions of mechanical and electrical UFGS. It requires coordination and editing to be used in conjunction with these UFGS.

Comments and suggestions on this guide specification are welcome and should be directed to the technical proponent of the specification. A listing of technical proponents, including their organization designation and telephone number, is on the Internet.

Recommended changes to a UFGS should be submitted as a Criteria Change Request (CCR).

Use of electronic communication is encouraged.

Brackets are used in the text to indicate designer choices or locations where text must be supplied by the designer.
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PART 1 GENERAL

1.1 REFERENCES

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NOTE: Issue (date) of references included in project specifications need not be more current than provided by the latest guide specification. Use of SpecsIntact automated reference checking is recommended for projects based on older guide specifications.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

U.S. GREEN BUILDING COUNCIL (USGBC)

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

1.2 DEFINITIONS

a. "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.

b. "Commissioning (Cx)" is a comprehensive and systematic process to verify that the building systems perform as designed to meet Government requirements and the design intent.

c. The "Commissioning Plan" (Cx Plan) is an overall plan that provides the structure, schedule and coordination planning for the Cx process.

d. "Data logging" records data such as flows, currents, status, and pressures over time using stand-alone data loggers separate from the control system.

e. "Deferred functional tests" are performed after substantial completion, due to partial occupancy, equipment, seasonal requirements, design, or other site conditions that disallow the test from being performed before substantial completion.

f. A "deficiency" is a condition in the installation or function of a component, piece of equipment, or system that is not in compliance with the Contract documents.

g. The "design intent" represents the ideas, concepts, and criteria that are conveyed through the Contract documents.

h. "Factory testing" tests equipment on-site or at the factory by factory personnel.

i. A "functional performance test" (FT) tests the dynamic function and operation of equipment and systems under full operation using manual (direct observation) or monitoring methods. For example, 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.

j. "Indirect indicators" indicate a response or condition, such as a reading from a control system screen reporting a damper to be 100 percent closed.

k. A "manual test" uses hand-held direct reading instruments, immediate control system readouts, or direct observation to verify performance (contrasted to analyzing monitored data taken over time to make the observation).

l. "Nonconformance" means a piece of equipment or a system does not perform properly or comply with the design intent.

m. An "overwritten value" is a sensor value in the building control system that is overridden to see the response of a system. For example, changing the outside air temperature value from 10 degrees C50 degrees F to 24 degrees C75 degrees F to verify economizer operation. See also "simulated signal."

n. "Phased commissioning" is completed in phases (by floors or buildings, for example) due to the size of the structures or other scheduling issues, in order to minimize the total construction time.

o. A "prefunctional checklist" (PC) is a list of items to inspect and elementary component tests to conduct to verify proper installation of equipment, provided by the Contractor with the assistance of the Commissioning Agent. PCs 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). However, some PC 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). PCs augment and are combined with the manufacturer's startup checklist.

p. "Sampling" functionally tests only a fraction of the total number of identical or near identical pieces of equipment.

q. "Seasonal performance tests" are FTs that are deferred until the system(s) will experience conditions closer to their design conditions.

r. "Simulated conditions" are created conditions 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).

s. A "simulated signal" uses a signal generator to send an amperage, resistance or pressure to the transducer and DDC system to simulate a sensor value.

t. "Startup" includes the initial starting or activating of dynamic equipment and executing PCs.

u. "Test requirements" specify what modes, functions, and conditions shall be tested. The test requirements are not the detailed test procedures. The test requirements are specified in the individual sections of the Contract documents.

v. "Trending" uses the building control system for monitoring.

w. The "warranty period" involves the 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.

1.3 DESCRIPTION

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NOTE: The goals of total building commissioning are to improve the building delivery process, provide a safe and healthy facility, improve energy performance, reduce operating costs, provide operations and maintenance staff orientation and

training, and improve systems documentation. Fundamental building systems commissioning contributes to the following LEED prerequisite: EA Prerequisite 1. Additional commissioning contributes to the following LEED credit: EA3.

****

The Cx process shall encompass and coordinate system documentation, equipment startup, control system calibration, testing and balancing, performance testing, and training. Cx shall begin in the design phase by documenting the design intent and continue through the construction phase and warranty period with actual verification of performance. Cx shall be completed before substantial completion. Cx does not take away from or reduce the responsibility of the system designers or installing contractors to provide a finished and fully functioning product. Sample documents to help guide the Cx process are available for reference in Appendices A and B.

1.3.1 Process

****

NOTE: Ensure that the entitiy providing the services of the CA is defined for the project.

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The following activities outline the Cx tasks specified in this section and the general order in which they occur. The Commissioning Agent (CA), as specified in [Section 01 45 00.00 20 CONSTRUCTION QUALITY CONTROL][_____], shall coordinate all activities.

a. Review design development and construction documents and document the basis of design and design intent.

b. Conduct a scoping meeting to review the Cx process with the Cx team members.

c. Develop a Cx Plan.

d. Schedule additional meetings throughout construction with necessary parties attending, to plan, scope, coordinate, schedule future activities, and resolve problems.

e. Collect equipment documentation during normal submittals, including detailed startup procedures.

f. Review submittals.

g. Develop startup plans, startup documentation formats, and PCs to be completed during the startup process.

h. Perform startup and initial checkout.

i. Develop and execute FT procedures.

j. Correct items of nonconformance in materials, installation, or setup and retest the system.

k. Submit a Deficiency Report and Resolution Record.

l. Review documentation for completeness.

m. Complete and submit the Final Cx Report.

n. Review, pre-approve and coordinate Government personnel training and verify completion.

o. Perform deferred testing as specified and required, including unforeseen deferred tests, seasonal testing, short-term diagnostic testing, and end-of-warranty review.

1.3.2 Written Work Products

The Cx process generates a number of written work products. The Cx Plan shall list all the formal written work products, describe briefly their contents, who is responsible to create them, their due dates, who receives and approves them and the location in the specification to create them. In summary, the written products are:

Product	Developed By
Design and document review	CA
Draft and Final Cx Plan	CA
Meeting minutes	Contractor
Cx schedules	Contractor, CA, Contracting Officer
Equipment documentation submittals	Contractor
Sequence clarifications	Contractor
PCs	Contractor with CA assistance
Startup and initial checkout plan	Contractor, CA compiles existing documents
Completed startup, initial checkout, and PC forms	Contractor
TAB Plan	Contractor
Final TAB report	Contractor
Issues log (deficiencies)	CA
Cx Progress Record	CA
Deficiency reports	CA
FT forms	Contractor
Completed FT forms	Contractor
O&M manual data	Contractor
Cx record book	CA
Training Plan	Contractor, CA, Contracting Officer
Specific training agendas	Contractor
Final Cx Report	CA
Miscellaneous approvals	Contracting Officer

1.4 SUBMITTALS

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NOTE: Submittals must be limited to those necessary for adequate quality control. The importance of an item in the project should be one of the primary factors in determining if a submittal for the item should be required.

A "G" following a submittal item indicates that the submittal requires Government approval. Some submittals are already marked with a "G". Only delete an existing "G" if the submittal item is not

complex and can be reviewed through the Contractor's Quality Control system. Only a31 a "G" if the submittal is sufficiently important or complex in context of the project.

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

Submittal items not designated with a "G" are considered as being for information only for Army projects and for Contractor Quality Control approval for Navy projects.

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

SD-01 Preconstruction Submittals

Draft Cx Plan[; G][; G, [_____]]

Cx Schedule

Final Cx Plan[; G][; G, [_____]]; (LEED)

SD-02 Shop Drawings

Control Drawings

SD-03 Product Data

[Commissioned Equipment Data]

SD-06 Test Reports

Startup and prefunctional tests and checklists

Nonconformance and Approval in PCs and Startup

Test procedure forms

Progress reports and test results

SD-07 Certificates

Commissioning Agent Certification Letter

Calibration documentation

Calibration certification

SD-08 Manufacturer's Instructions

Startup and Checkout Plan

Controls Initial Checkout

TAB Plan

Test Procedures

SD-09 Manufacturer's Field Reports

TAB Reports[; G][; G, [_____]]

SD-10 Operation and Maintenance Data

[Training Plan

For each training session submit dates, start and finish times, and locations; outline of the information to be presented; names and qualifications of the presenters; and list of texts and other materials required to support training.]

SD-11 Closeout Submittals

Final Cx Report[; G][; G, [_____]]

[Systems Manual[; G][; G, [_____]]]

[TAB Documentation]

Review and Approval[; G][; G, [_____]]

Deficiency Report and Resolution Record

1.5 SYSTEMS TO BE COMMISSIONED

****
NOTE: LEED Prerequisite 1 does not require commissioning of bracketed items, but whole-building commissioning ensures proper operation.
****

The following equipment and systems shall be commissioned in accordance with the procedures described in this section.

a. HVAC&R systems (including ductwork and piping, on passive and mechanical systems)

b. HVAC&R controls

c. Plumbing systems and technologies (including water collection, treatment, and heating)

d. Lighting and daylighting systems (including lighting controls)

e. Renewable and alternative energy systems

[f. Electrical systems (including wiring, plugs, sensors, and metering equipment)]

[g. Building envelope technologies (including roof, walls, doors, and windows)]

[h. Fire protection systems (including ventilation and alarms)]

[i. Advanced technologies]

j. [_____]

1.6 COORDINATION

1.6.1 Commissioning Team

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NOTE: Subcontractors, engineers, and specialty consultants shall be a part of the Commissioning Team as appropriate to the product or system being commissioned.
****

The members of the Cx team shall consist of the CA, the Contractor, the Contracting Officer, subcontractors, QC Specialists, Government representative(s) including operation and maintenance (O&M) staff, and [_____]. All members shall work together and with vendors to fulfill their contracted responsibilities and meet the objectives of the Contract documents and Cx process. The CA shall regularly communicate with all members of the Cx team, keeping them apprised of Cx progress and scheduling changes through memos, progress reports, or other methods of communication.

1.6.2 Cx Schedule

The CA shall work with the Contractor and the Contracting Officer to schedule the Cx activities. The CA shall provide the initial schedule of primary events at the Cx scoping meeting. The Draft Cx Plan shall provide a format for this schedule, and both shall be submitted together. The CA shall provide sufficient notice to the Contractor and the Contracting Officer for scheduling Cx activities. The Contractor shall integrate all Cx activities into the master schedule. As construction progresses the CA shall update the Cx schedule with more details. Notify the Contracting Officer and CA ahead of time when Cx activities not yet performed or not yet scheduled will impact the construction schedule.

1.6.3 Meetings

1.6.3.1 Scoping Meeting

The Cx scoping meeting shall be scheduled by the CA within [90][_____] days of award of the construction Contract. The CA shall plan and conduct the Cx scoping meeting with the entire Cx team in attendance. Meeting minutes shall be distributed to all parties within one week. The agenda shall include a review of each building system to be commissioned, including its

intended operation, Cx requirements, and completion and startup schedules. The scope of work, tasks, schedules, deliverables, and responsibilities for implementation of the Cx Plan shall be established. Information gathered from this meeting will allow the CA to update the Cx Plan, which shall also be distributed to all parties.

1.6.3.2 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. These meetings shall be held [monthly][_____], until the final three months of construction when they shall be held weekly. Cx shall also be discussed in all weekly progress meetings.

1.7 RESPONSIBILITIES

The responsibilities of various parties in the Cx process are as specified. The Contracting Officer and CA are not responsible for construction means, methods, job safety, or management function related to Cx on the job site.

1.7.1 CA Responsibilities

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NOTE: CA site visits and installation verification through checklists are required for LEED accreditation. Third-party CA submittal review contributes to the following LEED credit: EA3.

****

The CA is responsible for verification of compliance with the Cx Plan and the preparation of Cx checklists and reports. This shall involve coordinating and directing the Cx 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. All submittals applicable to systems being commissioned shall be reviewed and evaluated by the CA for compliance with Cx needs and the Contract documents. The CA shall ensure proper coordination and submission of all documents. During construction, the CA shall 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 potential revisions or substitutions related to the Cx process; and assist in resolving any discrepancies.

1.7.2 Contractor Responsibilities

The Contractor shall include and itemize the cost of Cx in the contract price, including the cost of sheaves and belts that may be required by testing, adjusting, and balancing (TAB). In each purchase order or subcontract written, requirements for submittal data, Cx documentation, O&M data, and training shall be included. During construction, the Contractor shall maintain as-built red-line drawings for all drawings and final CAD as-builts for contractor-generated coordination drawings. These drawings shall be updated after completion of Cx (excluding deferred testing).

1.8 COMMISSIONING PLAN

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NOTE: The intent of this Plan is to evoke questions, expose issues, and resolve them with input from the entire Cx team early in construction. A Cx Plan is required for LEED accreditation.

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The CA shall develop a Draft Cx Plan to identify how Cx activities will be integrated into general construction and trade activities. Appendix A is a template for the Plan, also available on the PECI website. The Plan shall identify how Cx responsibilities are distributed. The Specifications will take precedence over the Cx Plan in the event of conflicting requirements between the two. The Cx Plan shall include the following components:

a. A brief overview of the Cx process, including goals, objectives, and general project information. Briefly describe the Quality Control (QC) and the O&M Support Information Program requirements for the project. Provide copies of [Section 01 45 00.00 20 CONSTRUCTION QUALITY CONTROL][Section 01 45 04.00 10 CONTRACTOR QUALITY CONTROL] and Section 01 78 23 OPERATION AND MAINTENANCE DATA to supplement the description.

b. A list of systems to be commissioned.

c. Identification of Cx participants and responsibilities. Provide a final copy of Sections I through V and Section XIII from the Construction QC Plan.

d. A description of the management, communication, and reporting of the Cx Plan.

e. An outline of the Cx process scope including:

1. Documentation of basis of design and design intent.

2. Startup and testing procedures, including sampling procedures. Provide copies of Sections VII and VIII of the QC Plan.

3. Observation procedures. Provide a copy of Sections IX, X, XII, and XIV of the QC Plan. Highlight the requirements for verification of the correct installation of all systems.

4. System performance verification.

5. Submittal review procedures. Provide a copy of Section VI of the QC Plan.

6. O&M documentation. Describe the information to be provided to the client as required by Section 01 78 23 OPERATION AND MAINTENANCE DATA.

7. Training activities. Provide a copy of Section XV of the QC Plan.

8. Warranty period activities.

f. A list and description of the written work products, as specified in the paragraph Written Work Products.

g. An activity schedule.

h. A description of the rigor, scope, and procedures of testing and acceptance. Provide a copy of Section VII of the QC Plan.

The Draft Cx Plan shall be submitted to the Contracting Officer before the scoping meeting. Within [30][_____] days after the initial Cx scoping meeting the CA shall update and submit the Draft Cx Plan for Contracting Officer final review. The CA shall adjust the Draft Cx Plan as required and submit as the Final Cx Plan prior to commencement of work. The Final Cx Plan shall include specific scheduling of required testing procedures for commissioned equipment and systems. A Commissioning Agent Certification Letter signed by the CA shall be submitted, certifying the Cx Plan has been successfully executed and the design intent of the facility has been achieved.

[1.9 CX TEAM TRAINING

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NOTE: Training shall be required for Cx team members unfamiliar with systems or concepts included in this project. The CA shall determine which members need training, and to what extent.
****

The Contractor shall provide training according to a written training plan to Cx team members as determined by the CA prior to commencement of construction. The first training session shall describe the overall system design concept and the design concept of each equipment section. This presentation shall include a review of 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 systems, and/or outside air strategies, as determined by the CA. For the primary HVAC equipment, the Contractor shall provide a short discussion of the control of the equipment during the mechanical or electrical training. One training session shall include a presentation discussing the use of the blank FT forms for recommissioning equipment.

][1.10 COMMISSIONED EQUIPMENT DATA

****
NOTE: Include this paragraph if more data is needed for the commissioning process than is already specified in the technical sections and in Section 01 78 23 OPERATION AND MAINTENANCE DATA.
****

The CA shall request in writing from the Contractor specific information needed about each piece of commissioned equipment or system to fulfill requirements of the Cx Plan, and shall review and evaluate this information for compliance with Cx needs, in accordance with this section and Section 01 33 00 SUBMITTAL PROCEDURES. This information shall include [normal cut sheets;] [construction documents;] [addenda;] [change orders;] [approved submittals and shop drawings;] [redlined as-builds;] [full details of any required testing;] [fan and pump curves;] [full factory testing reports, if any;] and [_____]. [In addition, the installation, startup, and checkout materials that are shipped inside the equipment and the actual field checkout forms to be used by the factory or field technicians shall be submitted to the CA.] The CA may request further documentation as

necessary for the Cx process. Any request for additional data shall be made prior to receipt of normal submittal data from equipment manufacturers. This information is to be used in the Cx process prior to the regular formal O&M manual submittals, and shall be compiled and maintained in a building systems book to be included in the O&M manuals.

]1.11 REPORTING

The CA shall provide Cx progress reports monthly to the Contracting Officer and Cx team, with increasing frequency as construction and Cx progress. Sample standard forms shall be provided and referenced in the Cx Plan. Example standard forms are available for reference in Appendix B and on the PECI website. Testing or review approvals and nonconformance and deficiency reports shall be made regularly.

1.11.1 Final Cx Report

****
NOTE: A Final Cx Report is required for LEED accreditation.
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The CA shall compile a Final Cx Report focusing on evaluating Cx process issues, and provide four copies to the Contracting Officer within 30 days after occupancy. The report shall summarize all of the tasks, findings, conclusions, and recommendations of the Cx process. A list of participants and roles, brief building description, overview of Cx and testing scope, and general description of testing and verification methods shall be included. The CA shall provide the following for each piece of equipment:

a. Assessment of how the equipment meets the specifications and design intent.

b. Equipment installation verification.

c. O&M documentation evaluation.

d. Operator training evaluation.

e. Assessment of the value of the Cx process.

Specifically list all outstanding nonconformance items. Each nonconformance issue shall be referenced to the specific item where the deficiency is documented. List any uncorrected compromises in the environmentally responsive features. List recommendations such as improvements to equipment or operations, future actions including testing justified by seasonal conditions, or Cx process changes. Include a brief description of the verification method used and observations and conclusions from the testing of each piece of equipment. All acquired Cx documentation, including completed FTs, logs, minutes, reports, deficiency lists, communications, findings, and unresolved issues, shall be compiled in appendices and provided with the Final Cx Report.

[1.11.2 TAB Documentation Requirements

The TAB contractor will compile and submit a final report containing an explanation of the methodology, assumptions, test conditions, and results in a clear format with designations of all uncommon abbreviations and column headings. 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.

][1.11.3 Systems Manual

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NOTE: Include this paragraph if specifying additional commissioning.
****

The CA shall develop an indexed systems manual to be submitted with the Final Cx Report. The following information shall be compiled into a single manual, regardless of repetition with the O&M manuals:

a. Final version of basis of design and design intent.

b. As-built sequences of operations for all equipment as provided by subcontractors, including time-of-day schedules and schedule frequency, control drawings, and detailed point listings with ranges and initial setpoints.

c. Ongoing operating instructions for all integrated building systems.

d. FT results, blank test forms, and recommended schedule for ongoing testing.

e. Seasonal operational guidelines.

f. Recommendations for recalibration frequency of sensors and actuators by type and use.

g. Single line diagrams of each commissioned system.

h. Troubleshooting table for ongoing achievement of the design intent.

i. Guidelines for continuous maintenance of the design intent and basis of design.

]PART 2 PRODUCTS

2.1 TEST EQUIPMENT

Equipment shall be maintained in good repair and operational condition throughout the duration of use on this project.

2.1.1 Equipment Provisions

The Contractor shall provide all test equipment necessary to perform startup and initial checkout and required FT. Special equipment, tools and instruments available only from the vendor, specific to a piece of equipment, and required for testing equipment shall be turned over to the Government after testing has been completed, except for stand-alone data logging equipment. Data logging equipment and software required to test equipment shall not become the property of the Government.

2.1.2 Equipment Calibration

All testing equipment shall be of sufficient quality and accuracy to test and measure system performance within the tolerances specified. Unless

otherwise noted, the following minimum requirements apply. Temperature sensors and digital thermometers shall have a certified calibration within the past year to an accuracy of 0.5 degrees C0.9 degrees F and a resolution of plus or minus 0.1 degrees C0.2 degrees F. Pressure sensors shall have an accuracy of plus or minus 2.0 percent of the value range being measured (not the full range of the 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. Calibration documentation of all testing equipment shall be turned in with each testing episode. Serial numbers of equipment and standards used for QC, zeroing, and calibration shall be included.

PART 3 EXECUTION

3.1 STARTUP AND PREFUNCTIONAL CHECKOUT

****
NOTE: Startup and checkout are required for LEED accreditation.
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Each piece of equipment or system to be commissioned shall receive a full prefunctional checkout. No sampling strategies shall be used. Equipment shall not be temporarily started for Cx.

3.1.1 Responsibilities

The Contractor has startup responsibility and shall complete systems and subsystems so they are fully functional and meeting the design objectives of the Contract documents. The Cx procedures and FT do not relieve or lessen this responsibility or shift that responsibility partially to the CA or the Government. Parties responsible for PC execution and startup shall be identified in the Cx scoping meeting and in the PCs.

3.1.2 Startup and Checkout Plan

The CA shall assist the Contractor in developing PCs and detailed startup 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.

3.1.2.1 PCs

****
NOTE: PCs are important to ensure that the equipment and systems are hooked up and operational. These ensure that FT (in-depth system checkout) may proceed without unnecessary delays.
****

The PCs shall indicate required procedures to be executed as part of startup and prefunctional checkout of the systems. The Contractor shall determine which trade is responsible for executing and documenting each of the line item tasks and note that trade on the PC. Each task may have more than one trade responsible for its execution.

3.1.2.2 Startup

The Contractor shall develop the full startup plan and submit the plan to the CA for review and approval. The CA shall review and evaluate the procedures and the procedure documentation format, noting any procedures that need to be revised or added. The plan shall contain a minimum of the following:

a. PCs.

b. The manufacturer's standard written startup procedures copied from the installation manuals with check boxes by each procedure and a summary statement with a signature block added at the end.

c. The manufacturer's field checkout sheets.

3.1.3 Execution of PCs and Startup

Four weeks prior to startup, the Contractor shall schedule startup and checkout activities with the Contracting Officer and CA. The performance of the PCs, startup, and checkout shall be directed and executed by the Contractor. The Contractor shall provide skilled technicians to execute starting of equipment and shall 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. The CA [or Contracting Officer's representative] 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 Contracting Officer. A minimum of [four][_____] units shall be witnessed on any one building, or a minimum of [20][__] percent of the total number of identical or very similar units. For lower-level components of equipment (e.g., VAV boxes, sensors, controllers), the CA shall observe a sampling of the prefunctional and startup procedures. Sampling shall occur according to the procedures identified in the Cx Plan.

3.1.4 Documentation

After startup completion, the Contractor shall provide the CA with a signed and dated copy of the completed startup and prefunctional tests and checklists. Only individuals that have direct knowledge and witnessed that a line item task on the PC was actually performed shall initial or check that item off. Witnessing supervisors shall not fill out these forms.

3.1.5 Nonconformance and Approval in PCs and Startup

The Contractor shall clearly list any outstanding items of the startup 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 shall be provided to the Contracting Officer and the CA within two days of test completion. The CA shall review the report and submit either a nonconformance report or an approval form to the Contracting Officer. The CA shall work with the Contractor to correct and retest deficiencies or uncompleted items. The CA will involve the Contracting Officer and others as necessary. The Contractor 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 startup report and a Statement of Correction on the original nonconformance report. When satisfactorily completed, the CA shall recommend approval of the execution of the PCs and

startup of each system to the Contracting Officer using a standard form.

3.1.6 Phased Commissioning

The project may require startup and initial checkout to be executed in phases. This phasing shall be planned and scheduled in a coordination meeting of the CA, Contracting Officer, and the Contractor. Results will be added to the master and Cx schedule.

3.2 SENSOR AND ACTUATOR CALIBRATION

All field-installed temperature, relative humidity, CO2 and pressure sensors and gages, and actuators (dampers and valves) on all equipment shall be calibrated. Test instruments shall have had a certified calibration within the last 12 months. Sensors installed in the unit at the factory with calibration certification provided need not be field calibrated. Procedures used shall be fully documented on the PCs or other suitable forms, along with written documentation of initial, intermediate and final results.

3.2.1 Calibration Methods

Alternate methods may be used, if approved by the Government beforehand.

3.2.1.1 All Sensors

The Contractor shall verify that all sensor locations are appropriate and away from causes of erratic operation. Verify that sensors with shielded cables are grounded only at one end. For sensor pairs that are used to determine a temperature or pressure difference, verify they are reading within 0.2 degrees C0.4 degrees F of each other for temperature and within a tolerance of each other equal to two percent of the reading for pressure. Tolerances for critical applications may be tighter.

3.2.1.2 Sensors Without Transmitters

Make a reading with a calibrated test instrument within 6 inches150 mm of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, or building automation system (BAS)) is within the tolerances listed in the table below in paragraph Tolerances, Standard Applications of the instrument-measured value. If not, install offset in BAS, calibrate, or replace sensor.

3.2.1.3 Sensors With Transmitters

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 inches150 mm of the site sensor. Verify that the sensor reading (via the permanent thermostat, gage, or BAS) is within the tolerances listed in the table below in paragraph Tolerances, Standard Applications of the instrument-measured value. If not, replace sensor and repeat. For pressure sensors, perform a similar process with a suitable

signal generator.

3.2.2 Tolerances, Standard Applications

Sensor	Required Tolerance (+/-)
Cooling coil, chilled and condenser water temps	0.4 C0.7 F
Flow rates, water	4% of design
Relative humidity	4% of design
AHU wet bulb or dew point	2.0 C3.6 F
Combustion flue temps	5.0 C9.0 F
Hot water coil and boiler water temp	1.5 C2.7 F
Oxygen or CO2 monitor	0.1% pts
Outside air, space air, duct air temps	0.4 C0.7 F
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	2.5 mm1.0 inch of Hg

3.2.3 Valve and Damper Stroke Setup and Check

3.2.3.1 EMS Readout

For all valve and damper actuator positions checked, verify the actual position against the BAS readout. Set pumps or fans to normal operating mode. Command valve or damper closed, visually verify that valve or damper is closed and adjust output zero signal as required. Command valve or damper open, verify position is full open and adjust output signal as required. Command valve or damper to [three] [_____] intermediate positions. If actual valve or damper position doesn't reasonably correspond, replace actuator or add pilot positioner (for pneumatics).

3.2.3.2 Closure for Heating Coil Valves (NO)

Set heating setpoint 2.2 degrees C4.0 degrees F above room temperature. Observe the valve open. Remove control air or power from the valve and verify that the valve stem and actuator positions do not change. Restore to normal. Set heating setpoint to 2.2 degrees C4.0 degrees F below room temperature. Observe the valve close. For pneumatics, by override in the EMS, increase pressure to valve by 2109 K/m21361 psi (do not exceed actuator pressure rating) and verify that valve stem and actuator position do not change. Restore to normal.

3.2.3.3 Closure for Cooling Coil Valves (NC)

Set cooling setpoint 2.2 degrees C4.0 degrees 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 11 degrees C20 degrees F below room temperature. Observe valve open. For pneumatics, by override in the EMS, increase pressure to valve by 5 K/m23 psi (do not exceed actuator pressure rating) and verify that valve stem and actuator position do not change. Restore to normal.

3.3 CONTROLS

Controls shall be tested and verified after startup and prefunctional checkout and after sensor and actuator calibration, as specified here and in [Section 23 09 54.00 20 DIRECT DIGITAL CONTROL SYSTEMS][Section 23 09 53.00 20 SPACE TEMPERATURE CONTROL SYSTEMS][Section 23 09 23 DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS]. The Contractor shall be responsible for Cx activities related to controls. Before initial startup, the Contractor shall gather and review the current control sequences and interlocks and with the CA write detailed testing procedures.

3.3.1 Control Drawings

Submit control drawings that include complete detailed sequences of operation for each piece of equipment, regardless of the completeness and clarity of the sequences in the specifications.

3.3.1.1 Content

Drawings shall include:

a. An overview narrative of the system (one or two paragraphs) generally describing system purpose, components, and function.

b. All interactions and interlocks with other systems.

c. Detailed delineation of control between any packaged controls and the BAS, 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.

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NOTE: Equipment manufacturers' stock sequences may be included for packaged controlled equipment, but will generally require additional narrative.
****

e. Startup 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 (e.g., setbacks, setups, resets).

l. Detailed sequences for all control strategies (e.g., economizer control, optimum start/stop, staging, optimization, demand limiting).

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. Include any other control settings, fixed values, or delays that will be useful during testing and operating the equipment.

q. Schedules, if known.

3.3.1.2 Format

To facilitate referencing in testing procedures, 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. The control drawings shall have a key to all abbreviations, and shall contain graphic schematic depictions of the systems and each component. The schematics shall include the system and component layout of any equipment that the building control system monitors, enables, or controls, including equipment primarily controlled by packaged or integral controls. Provide a full points list with the following included as a minimum for each point:

a. Controlled system

b. Point abbreviation

c. Point description (e.g., DB temp, airflow)

d. Display unit

e. Control point or setpoint (Yes / No) (Point that controls equipment and can have its setpoint changed)

f. Monitoring point (Yes / No) (Point that does not control or contribute to the control of equipment, but is used for operation, maintenance, or performance verification)

g. Intermediate point (Yes / No) (Point whose value is used to make a calculation which then controls equipment; e.g., space temperatures that are averaged to a virtual point to control reset)

h. Calculated point (Yes / No) ("Virtual" point generated from calculations of other point values)

The Contractor shall keep the Contracting Officer and the CA informed of all changes to this list during programming and setup. An updated as-built version of the control drawings and sequences of operation shall be included in the final controls O&M manual submittal, as specified in Section 01 78 23 OPERATION AND MAINTENANCE DATA.

3.3.2 Controls Initial Checkout

Indicate what tests on what systems should be completed prior to TAB using the building control system for TAB work. Coordinate with the CA and TAB contractor for this determination. Provide a signed and dated certification to the CA and Contracting Officer upon completion of the checkout of each controlled device, equipment, and system prior to FT for each piece of equipment or system, that all system programming is complete

with reference to all aspects of the Contract documents, except FT requirements. Beyond the control points necessary to execute all documented control sequences, provide monitoring, control, and virtual points as specified. 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). The 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 building control system prior to FT. At a minimum, the plan shall include for each type of equipment controlled by 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.

3.3.3 Controls FT

The CA shall assist the Contractor in executing controls testing. Using a skilled technician who is familiar with this building, execute the FT of the controls system as specified for the controls contractor in [Section 23 09 54.00 20 DIRECT DIGITAL CONTROL SYSTEMS][Section 23 09 53.00 20 SPACE TEMPERATURE CONTROL SYSTEMS][Section 23 09 23 DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS]. Execute all control system trend logs specified in [Section 23 09 54.00 20 DIRECT DIGITAL CONTROL SYSTEMS][Section 23 09 53.00 20 SPACE TEMPERATURE CONTROL SYSTEMS][Section 23 09 23 DIRECT DIGITAL CONTROL FOR HVAC AND OTHER LOCAL BUILDING SYSTEMS]. The building control system shall be sufficiently tested and approved by the CA and the Contracting Officer before it is used for TAB or to verify performance of other components or systems.

3.4 TAB

****

NOTE: The requirements for paragraph TAB are supplemental to Section 23 08 00.00 20 HVAC TESTING/ADJUSTING/BALANCING and Section 23 05 93.00 10 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS. They help to ensure TAB is completed in a manner that is complementary to Cx. Include paragraph TAB unless TAB has otherwise been coordinated with Cx.

****

TAB shall be completed after controls are tested, checked out, and adjusted. The Contractor shall be responsible for TAB preparation and activities, as specified here and in [Section 23 08 00.00 20 HVAC TESTING/ADJUSTING/BALANCING][Section 23 05 93.00 10 TESTING, ADJUSTING, AND BALANCING OF HVAC SYSTEMS].

3.4.1 TAB Plan

Six weeks prior to starting TAB, submit an outline of the TAB plan and approach for each system and component to the CA, Contracting Officer, and the controls contractor. This plan shall be developed after the TAB contractor has some familiarity with the building control system, and shall be reviewed by the CA. The TAB contractor shall review the TAB plan to determine the capabilities of the building control system toward completing TAB. The submitted plan shall include:

a. Certification that the TAB contractor has reviewed the construction documents and the systems with the Contractor 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. 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 (e.g., terminal flow calibration for each terminal type, diffuser proportioning, branch / submain proportioning, total flow calculations, rechecking, diversity issues, expected problems and solutions). Criteria for using air flow straighteners or relocating flow stations and sensors shall 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, and 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) pilot traverse, SA or RA flow stations. Water: pump curves, circuit setter, flow station, ultrasonic.).

i. 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 the TAB contractor understands the outside air ventilation criteria under all conditions.

l. Details of whether and how minimum outside air infiltration will be verified and set, and for what level (e.g., total building, zone).

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 (e.g., by floor, by building).

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).

3.4.2 Scheduling

Prepare a preliminary schedule for Division 15 pipe and duct system testing, flushing, cleaning, equipment startup, and TAB start and completion for use by the CA. Update the schedule as appropriate, and notify the Contracting Officer and CA prior to the start of each activity.

3.4.3 Preparation

Meet with the TAB contractor prior to beginning TAB. Provide the TAB contractor any needed unique instruments for setting terminal unit boxes and instructions for their use; for instance, handheld control system interface for use around the building during TAB. For a given system, have

required PCs, calibrations, startup, and selected FTs completed and approved by the CA prior to TAB. Install a P/T plug at each water sensor that is an input point to the control system. List and clearly identify on the as-built drawings the locations of all air-flow stations. Provide test holes in ducts and plenums where directed by the TAB contractor to allow air measurements and air balancing, providing an approved plug. Provide temperature and pressure taps according to the Contract documents for TAB and Cx testing. Provide sufficient FT of the HVAC control system and evaluate its use for TAB before TAB is executed. Put all HVAC equipment and systems into operation and continue the operation during each working day of TAB and Cx, as required.

3.4.4 TAB Execution

Provide a qualified technician to operate the controls to assist the TAB contractor in performing TAB, or provide sufficient training for the TAB contractor to operate the system without assistance. The CA shall witness the HVAC piping test and flushing procedures and the ductwork testing and cleaning procedures, sufficiently to be confident that proper procedures are followed. Testing results shall be documented and copies provided to include in the O&M manuals. Notify the Contracting Officer of any deficiencies in results or procedures. The CA shall evaluate air and water systems balancing by initiating spot testing, by reviewing completed reports, and by selected site observation. Air and water TAB shall be completed with discrepancies and problems remedied before FT of the respective air- or water-related systems.

3.4.5 TAB Reports

A running log of events and issues shall be kept by the TAB contractor. Submit hand-written reports of discrepancies, deficient or uncompleted work by others, contract interpretation requests, and lists of completed tests to the CA and Contracting Officer a minimum of twice a week. Communicate in writing to the controls contractor all setpoint and parameter changes made or problems and discrepancies identified during TAB which affect the building control system setup and operation. Provide a draft TAB report to the CA within two weeks of TAB completion. The report shall 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 shall follow the latest and most rigorous reporting recommendations by the National Environmental Balancing Bureau. Provide the CA and Contracting Officer with any requested data gathered but not shown on the draft reports. Provide a final TAB report with details for CA review and Contracting Officer's approval.

3.5 FUNCTIONAL PERFORMANCE TESTING

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NOTE: The objective of FT is to demonstrate that each system is operating according to the documented design intent and Contract documents. FT 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. Traditional air or water TAB shall not replace FT. TAB's primary work is setting up the system flows and pressures as specified, while FT

shall verify that which has already been set up. Functional testing is required for LEED accreditation.

****

The CA shall direct, witness, and document the FT of all equipment and systems. The Contractor shall execute the tests with skilled technicians provided under the direction of the CA. Systems shall be tested under all modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, full range of part- and full-load) and under abnormal modes and conditions (power failure, interlocks with other equipment, alarms, [freeze condition,][low oil pressure,][no flow,]equipment failure). The Contractor shall verify that systems are run through all the building control system's sequences of operation, and components shall be verified to be responding as the sequences state. Systems shall not leak. The CA shall assist the Contractor to develop the FT procedures in a sequential written form, and coordinate, oversee, and document the actual testing. The CA shall engage Cx service personnel that specialize in the types of inspections and tests to be performed. Inspection and testing service agencies shall be members of the Building Commissioning Association.

3.5.1 Development of Test Procedures

****

NOTE: The purpose of any given specific test is to verify and document compliance with the stated criteria of acceptance given on the test form.

****

Before test procedures are written, the Contractor shall obtain all requested documentation regarding equipment sequence of operation and testing procedures, including procedures for equipment installed by factory representatives and a current list of change orders affecting equipment or systems. The change orders shall include an updated points list, program code, control sequences, and parameters. Using the testing parameters and requirements found in the technical sections of commissioned equipment and systems the Contractor shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. The Contractor shall assist the CA 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. Prior to execution, the Contractor shall provide a copy of the test procedures to the CA who shall review the tests for feasibility, safety, equipment operation, sequences, and warranty protection. The test procedure forms shall include the following, at a minimum:

a. System and equipment or component name(s) and configuration(s).

b. Equipment location and ID number.

c. Unique test ID number, and reference to unique PC and startup documentation ID numbers.

d. Date.

e. Project name.

f. Participating parties.

g. A copy of the section describing the test requirements.

h. A copy of the specific sequence of operations or other specified parameters being verified.

i. Formulas used in any calculations.

j. Required pre-test field measurements.

k. Instructions for setting up the test, including special cautions, alarm limits, or other equipment-specific information.

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

m. Acceptance criteria of proper performance with a Yes / No check box to allow for clear marking of whether or not proper performance of each part of the test was achieved.

n. A section for comments.

o. Signature and date blocks for the CA, Contractor, and Contracting Officer.

3.5.2 Test Methods

3.5.2.1 Functional Performance

FT and verification shall be achieved by manual testing or by monitoring the performance and analyzing the results using the energy management control system's trend log capabilities or by stand-alone data loggers. A combination of methods may be required to test the complete sequence of operations. The [Contractor and]CA shall determine which method, or combination of methods, is most appropriate for tests that do not have a method specified. The Contractor shall provide FT of commissioned equipment and systems. The CA [or Contracting Officer's representative] shall analyze any functional performance trend logs and monitoring data to verify performance, and witness and evaluate manual FTs performed by the Contractor. The Contractor shall assist the CA in interpreting the monitoring data, as necessary.

3.5.2.2 Simulated Conditions

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NOTE: 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.

****

Simulating conditions (not by an overwritten value) shall be allowed only when timing the testing to experience actual conditions is not practical. Sensors, transducers, and devices shall have been calibrated before simulating conditions.

3.5.2.3 Overwritten Values

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NOTE: Using overwritten values 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 in other ways is preferable.
****

Overwriting sensor values to simulate a condition shall be allowed only when simulating conditions in other ways is not practical, and shall be used with caution. Sensors, transducers and devices shall have been calibrated before overwriting values.

3.5.2.4 Altering Setpoints

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NOTE: An example of altering a setpoint is as follows: to see the AC compressor lockout work at an outside air temperature below 12 degrees C54 degrees F, when the outside air temperature is above 12 degrees C54 degrees F, temporarily change the lockout setpoint to be 2 degrees C4 degrees F above the current outside air temperature.
****

Altering setpoints to test a sequence is an acceptable alternative to overwriting sensor values when simulating conditions in other ways is not practical.

3.5.2.5 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 building control system represent actual conditions and responses. Much of this verification shall be completed during prefunctional testing.

3.5.2.6 Setup

Each function and test shall be performed under conditions that simulate actual conditions as close as possible. The Contractor shall provide materials, system modifications, and other necessities to produce the flows, pressures, temperatures, or other values necessary to execute the test according to the specified conditions. Where equipment requires integral safety devices to stop or prevent equipment operation unless minimum safety standards or conditions are met, FT procedures shall demonstrate the actual performance of safety shutoffs in real or closely-simulated conditions of failure. At completion of the test, the Contractor shall return all affected building equipment and systems, due to these temporary modifications, to their pre-test conditions.

3.5.2.7 Sampling

****
NOTE: A common sampling strategy referenced 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 FTs, 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 Contractor to perform and document a checkout of the remaining units, prior to continuing with functionally testing the remaining units.
****

Multiple identical pieces of non-life-safety or otherwise non-critical equipment may be functionally tested using a sampling strategy. The sampling strategy shall be developed by the CA. 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. If, after three attempts at testing the specified sample percentage, failures are still present, then all remaining units shall be tested at the Contractor's expense. No sampling is allowed in PC execution.

3.5.3 Coordination and Scheduling

FT shall be performed after PCs, startup, calibration, and TAB are complete for a given system. The CA shall schedule FTs through the Contractor and Contracting Officer. Testing shall proceed 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 shall be checked.

3.5.4 Documentation

The CA shall document the results of all FTs using the specific test procedure forms developed by the Contractor for that purpose. The Contractor shall submit copies of the completed forms with the O&M manual data and as part of the Cx Report.

3.6 NONCONFORMANCE

Every effort shall be made to expedite the testing process and minimize unnecessary delays, while not compromising the integrity of the procedures. 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 by direction from the Contracting Officer. Nonconformance and deficiencies observed in materials, installation, or operation shall be addressed immediately, in terms of notification to responsible parties, and providing recommended actions to correct

deficiencies. The Contractor shall have responsibility for resolving construction deficiencies, and the CA shall assist with problem solving as necessary. If a design revision is deemed necessary and approved by the Contracting Officer, the designer shall have responsibility for providing design revision. The CA shall maintain a master deficiency and resolution log, and shall provide the Contracting Officer with written progress reports and test results with recommended actions.

3.6.1 Procedure

All deficiencies or nonconformance issues shall be noted and reported to the Contracting Officer on a standard nonconformance form. The Contractor shall report in writing to the CA and Contracting Officer weekly, or at a minimum as often as Cx meetings are being scheduled, concerning the status of each apparent outstanding discrepancy identified during Cx. The report shall include explanations of any disagreements and proposals for their resolution, and a copy shall be included in the deficiency report and resolution record. Corrections of minor deficiencies may be made during the tests at the discretion of the CA, and the deficiency and resolution shall be documented on the test procedure form.

3.6.1.1 Non-Disputed Deficiencies

When a deficiency is identified, the CA shall discuss the issue with the Contractor. When there is no dispute on the deficiency and the Contractor accepts responsibility to correct it, the CA shall document the deficiency, the adjustments or alterations required to correct it, and the Contractor's response and intentions. The next test or sequence may then be performed. After the day's work, the CA shall submit all the nonconformance reports to the Contracting Officer for signature. Copies shall be provided to the Contractor and Contracting Officer. The Contractor shall correct the deficiency, sign the statement of correction at the bottom of the nonconformance form certifying that the equipment is ready to be retested and shall send it back to the CA. The CA shall reschedule the test and the test shall be repeated as specified in the paragraph Retesting.

3.6.1.2 Disputed Deficiencies

If there is a dispute about a deficiency, regarding whether it is a deficiency or who is responsible, the deficiency shall be documented on the nonconformance form with the Contractor's response and a copy given to the Contracting Officer and Contractor. Resolutions shall be made at the lowest management level possible. Additional parties shall be brought into the discussions as needed. Final interpretive and acceptance authority is with the Contracting Officer. The CA shall document the resolution process. Once the interpretation and resolution have been decided, the Contractor shall correct the deficiency, sign the statement of correction on the nonconformance form and provide it to the CA. The CA shall reschedule the test and the test shall be repeated as specified in the paragraph Retesting.

3.6.2 Retesting

The cost to retest a prefunctional test or FT shall be solely the responsibility of the Contractor. Any required retesting by the Contractor shall not be considered a justified reason for a claim of delay or for a time extension by the Contractor. The CA [or Contracting Officer's representative] shall witness retesting as necessary until satisfactory performance is achieved.

3.6.3 Failure Due to Manufacturer Defect

If the greater of 10 percent of, or three, identical pieces of equipment (size alone does not constitute a difference) 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 Contracting Officer. In such case, the Contractor shall provide the Contracting Officer with the following:

a. Within one week of notification from the Contracting Officer, the Contractor or manufacturer's representative shall examine all other identical units making a record of the findings.

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, and all proposed solutions which shall include full equipment submittals. The proposed solutions shall not significantly exceed the specification requirements of the original installation. The Contracting Officer shall determine whether a replacement of all identical units or a repair is acceptable.

c. Two examples of the proposed solution shall be installed by the Contractor and the Contracting Officer shall be allowed to test the installations for up to one week, upon which the Contracting Officer will decide whether to accept the solution.

d. Upon acceptance, the Contractor and 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.

3.6.4 Deficiency Report and Resolution Record

The CA shall submit original nonconformance forms with the deficiency report and resolution record at the end of the project. The deficiency report and resolution record shall contain documented items of nonconformance in materials, installation, or operation, including the master deficiency and resolution log, and documented results from startup, PCs, FT, and short-term diagnostic monitoring, as specified. Details of the components or systems found to be noncompliant with the drawings and specifications shall be included. Adjustments and alterations performed or required to correct the deficiencies and the responsible parties shall be identified.

3.7 DEFERRED TESTING

3.7.1 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 FT may be delayed upon approval of the Contracting Officer. These tests shall be conducted as soon as possible in the same manner as seasonal testing. Services of necessary parties shall be negotiated.

3.7.2 Seasonal Testing

The CA shall schedule, coordinate, and observe additional testing for seasonal variation in operations and control strategies during the opposite season to verify performance of the HVAC system and controls. The Contractor shall execute and document tests and correct deficiencies with facilities staff and the CA [or Contracting Officer's representative] witnessing. Testing shall be completed during the warranty period to fully test all sequences of operation. The Contractor shall make necessary revisions to O&M manuals and records due to the testing.

3.7.3 Short-Term Diagnostic Testing

After initial occupancy, the Contractor shall perform short-term diagnostic testing, using data acquisition equipment or the building automation system to record system operation over a two- to three-week period. The dynamic interactions between components in the building system shall be investigated. The scheduling, interaction between heating and cooling, and effectiveness of the HVAC system in meeting the comfort requirements shall be evaluated. The Contractor shall document tests and findings, and correct deficiencies according to the original testing requirements.

3.8 REVIEW AND APPROVAL

The CA shall validate that the testing requirements of this Contract are accomplished, and shall note each satisfactorily demonstrated function on the test form. Formal approval of the FT shall be made after review by the CA and Contracting Officer. The CA shall evaluate each test and report to the Contracting Officer using a standard form. The Contracting Officer shall give final approval on each test using the same form, and provide signed copies to the CA and the Contractor.

-- End of Section --