

Basis of Design

This section applies to commissioning of building mechanical systems.

Background

- The purpose of commissioning is to assure the Owner that all contract requirements are met and that the facilities are operating at optimum performance levels according to building-program established parameters.
- New facilities have become much more complex, requiring that new methods of start-up and operation be employed to assure that each facility will function as intended.
- There are many critical participants involved with a comprehensive building commissioning program. The obvious participants are the Contractors, Consultants, and the Owner. Additional specialists include a third party Commissioning Agent who is engaged directly by the Owner, and the Test Engineer who will be a member of the prime Contractor's team. Whereas, by contract, each will have clearly defined individual responsibilities, overall both become the essence of the final quality assurance program. The underlying objective is to deliver a fully operational facility that operates in accordance with the design intent.

Design Criteria

- Generally, for projects with a maximum allowable construction cost (MACC) exceeding \$3 million, the UW will hire a Commissioning Agent. This will be a firm skilled in commissioning facilities of the type represented by the specific project. In this situation, the firm will be referred to as the Commissioning Agent. The Commissioning Agent will be hired prior to construction to be available to work with the Design Team and Contractor. In some cases the Commissioning Agent may be hired during design to contribute expert advice before the project is bid and after the bid is awarded. UW Environmental Health and Safety shall serve as the commissioning agent for fire sprinkler systems. Commissioning of the life safety systems shall be coordinated with and approved by the UW Environmental Health and Safety.
- The specific duties of the Commissioning Agent are:
 - 1) Review the Contractor's systems start-up plans.
 - 2) Review the Contractor's equipment and component test procedures.
 - 3) Review the Contractor's systems and inter-systems functional performance test procedures.
 - 4) Witness, verify and approve satisfactory completion of equipment and component tests and systems and inter-systems functional performance tests.
 - 5) Review and approve specified documentation.
 - 6) When testing, adjusting and balancing (TAB) work is contracted separately by the Owner, coordinate the TAB firm's participation in the project.
 - 7) When commissioning has been successfully completed, recommend final acceptance to the Owner.
 - 8) Work with design consultant on developing FPT criteria to be implemented in the design document. Test Engineer will develop final FPT based on the criteria outlined in the design document.

- Generally, for projects with a MACC exceeding \$3 million, the contract documents will require the prime Contractor to engage a Test Engineer to organize, schedule, and conduct all equipment and apparatus tests and prepare and perform all system functional performance tests. This organizing, scheduling and testing will be presented to the Commissioning Agent and UW Environmental Health and Safety for fire/life safety projects for review and approval.
- The primary roles of the Test Engineer are to develop appropriate test procedures for all equipment/systems being tested, complying with the manufacturer's standards and procedures, and to ensure that all is successfully completed within the contract completion period.
- The specific duties of the Test Engineer are as follows:
 - 1) Develop test procedures and forms for documentation of all equipment tests, system functional tests, and cross system functional tests. Test procedures shall be in accordance with equipment manufacturer's recommendations, where applicable. Test procedures shall fully describe system configuration and steps required for each test; appropriately documented so that another party can repeat the tests with virtually identical results.
 - 2) Develop schedules for all testing; integrate testing into the master construction activity schedule; and coordinate all subcontractor testing.
 - 3) Review and approve all other functional performance tests, results, and documentation required by the contract documents; for all equipment and systems, as performed by subcontractors, vendors, and manufacturer's representatives.
 - 4) Submit test procedure schedule, procedures, forms, and other documentation to the Commissioning Agent and Owner for approval six months prior to starting any testing required by Commissioning Plan.
 - 5) Coordinate directly with each subcontractor on the project specific to their responsibilities and contractual obligations.
 - 6) Provide qualified personnel for participation in commissioning tests, including seasonal testing required after the initial commissioning.
 - 7) Provide engineering and technical expertise to oversee and direct the correction of deficiencies found during the commissioning process.
 - 8) Observe the start-up and initial testing of equipment by the Contractor and subcontractors, and then all final tests of equipment and systems.
 - 9) Manage all cross system testing such as HVAC, building automation, fire alarm, emergency power, life safety, elevators, etc.
 - 10) Note any inconsistencies or deficiencies in system operations and enforce system compliance or recommend to the Architect modifications to system design which will enhance system performance.
 - 11) Coordinate the required A/E, Commissioning Agent, and Owner testing participation and approval procedures, after verifying that pretests have been satisfactorily conducted and final tests are ready to be performed.
 - 12) In the event that a functional test fails, the cause of failure shall be determined and rectified as soon as possible, and then retested. If more than three functional tests of the same system(s) are required, the Contractor shall reimburse all associated costs for the extraordinary participation of the A/E, Commissioning Agent, and Owner's staff, as required by the particular test being performed.

- 13) Review operation and maintenance information and as-built drawings provided by the various subcontractors and vendors for verification, organization, and distribution.
 - 14) Obtain all documentation from tests and assemble a final test report to be submitted to the Architect and the Commissioning Agent for approval.
 - 15) Oversee and/or provide training for the systems specified in the division with coordination by the Divisions 15 and 16 subcontractors.
 - 16) Update Basis of Design by Owners representative.
- For projects with a MACC less than \$3 million the UW will hire a Commissioning Agent to perform the duties that would be performed by the Test Engineer. The Commissioning Agent may be hired prior to construction to be available to work with the Design Team and Contractor (Please consult with Engineering Services at early design phases). In some cases the Commissioning Agent may be hired during design to contribute expert advice before the project is bid and after the bid is awarded.
 - For projects with a MACC less than \$3 million, it may not be necessary to require the prime Contractor to engage a Test Engineer. The scope of commissioning and the extent of commissioning requirements may be reduced as may be appropriate to the complexity and sophistication of the specific project. These decisions must be made by the Consultant and the University, via specific discussion of the commissioning program, and all related decisions and commitments made prior to the end of the design development phase.
 - Even though a Test Engineer may not be required on projects with a MACC less than \$3 million, commissioning requirements for the project will still be incorporated into the contract documents. It shall also be required that the prime Contractor designate, in writing, a member of the construction team to be responsible for the commissioning program.
 - For all projects a critical requirement for the prime and subcontractors is development of the comprehensive test procedures for equipment and systems. This test is based on the operating criteria, test parameters, and acceptable results required. Many contractors have not had experience in this area. Therefore, someone who specializes (or has had experience) in development of test procedures is required.
 - The University has developed a library of test procedures for the range of equipment and systems it has commissioned. To a degree, there is a somewhat generic quality regarding test procedures for common equipment and systems. However, in every instance, such procedures must be carefully reviewed and adapted to the unique characteristics and design conditions of the project.
 - The University will make this material available to consultants and contractors for reference during design and construction. Doing so will help to reduce the time required for such development, develop more consistent testing/commissioning, and gradually improve the quality of the program.
 - Refer to the General Requirement, Functional Performance Testing, and Facility Start-up guide specifications following this design section.

Design Evaluation

The following information is required to evaluate the design:

- Schematic Design Phase: Provide a list of systems and equipment to be commissioned. Provide specification section Mechanical: Facility Start-up / Commissioning.

- Design Development Phase: Provide a preliminary scope of work description for systems and equipment to be commissioned.
- Construction Document Phase: Provide a final scope of work description for systems and equipment to be commissioned. Provide final design commissioning documents.

Construction Submittals

- Provide standard industry submittal requirements.

Related Sections

- Facilities Services Design Guide – Mechanical - General Requirements
- Facilities Services Design Guide – Mechanical - Plumbing
 - Potable and Nonpotable Water
 - Waste and Drains
 - Acid and Laboratory Wastes
 - Compressed Air, Vacuum, Natural Gas & Nitrogen
 - RO/DI
 - Plumbing Pressure Testing
- Facilities Services Design Guide – Mechanical - Heating, Ventilating and Air Conditioning
 - Process and Environmental Chilled Water
 - Central Cooling Water
 - Steam and Condensate
 - Hydronic Heating
 - Refrigeration
 - Air Handlers and Ventilation Fans
 - Filters
 - Coils
 - Ductwork and Duct Accessories
 - HVAC and HVAC Piping Pressure Testing
- Facilities Services Design Guide – Mechanical - Piping, Valves & Accessories
- Facilities Services Design Guide – Mechanical - Hangers and Supports
- Facilities Services Design Guide – Mechanical - Pumps
- Facilities Services Design Guide – Mechanical - Motors and VFDs
- Facilities Services Design Guide – Mechanical - Metering and Gauges
- Facilities Services Design Guide – Mechanical - Nonstructural Component Seismic Design
- Facilities Services Design Guide – Mechanical - Identification

- Facilities Services Design Guide – Mechanical - Insulation
- Facilities Services Design Guide – Mechanical - Water Treatment and Flushing
- Facilities Services Design Guide – Mechanical - Noise and Vibration Control
- Facilities Services Design Guide – Mechanical - Cold/Environmental Rooms
- Facilities Services Design Guide – Mechanical - Computer Server Rooms
- Facilities Services Design Guide – Mechanical - Environmental Control Systems
- Environmental Health & Safety Design Guide – Sprinkler Protection & Standpipes
- Facilities Services Design Guide – Mechanical - Testing, Adjusting and Balancing

Installation, Fabrication and Construction

- Standard industry practices are acceptable.

END OF DESIGN GUIDE SECTION

GUIDE SPECIFICATION

The following specification is intended as a guide only. The Consultant shall write the specifications to meet the project needs in consultation with the Owner.

MECHANICAL – COMMISSIONING: GENERAL REQUIREMENTS

PART 1 - GENERAL

1.01 DESCRIPTION

A. Purpose

1. The purpose of the commissioning process is to provide the University (Owner) assurance that the systems have been installed in the prescribed manner and will operate within the performance guidelines. Commissioning is intended to enhance the quality of system start-up and aid in the orderly transfer of systems to beneficial use by the Owner.
2. The Contractor verifies installation, provides scheduling and coordination of commissioning activities, performs training, starts up equipment, conducts functional performance testing, corrects deficiencies, performs retests, and provides documentation of the process.
3. The Commissioning Agent, hired directly by the Owner, provides the Owner an unbiased, objective view of the system's installation, documentation, operation, and performance.
4. Commissioning procedures and results will be observed by the Commissioning Agent. The Contractor is expected to verify the functional readiness of systems to be tested prior to performing the tests in the presence of the Commissioning Agent. A high rate of test failure will indicate that the Contractor has not adequately verified the readiness of the systems.

B. General

1. Furnish labor and material to accomplish building commissioning as specified herein.
2. Requirements of Commissioning Section shall be accomplished by a qualified Test Engineer, as specified in Section 01450.
3. The requirement for and responsibilities of the Test Engineer are indicated in Section 01450 and-Commissioning Section.
4. The Commissioning Agent is an independent contractor and will work under a separate contract directly with the Owner.
5. Unless noted otherwise, functional performance tests (FPTs) described under "Acceptance Criteria" in the various sections of this division, apply to all equipment and systems identified under "Systems / Equipment to be Tested."

1.02 RELATED WORK SPECIFIED ELSEWHERE

- A. Refer to Sections 01450, Mechanical – Commissioning, Facility Start-up, and Electrical – Commissioning for additional Contractor responsibilities relative to the commissioning process.
- B. Refer to Sections-00800, and 01700 for functional completion requirements.

1.03 COORDINATION

A. Provide overall coordination and management of the commissioning program as specified herein. The commissioning process will require cooperation of the Contractor, subcontractors, vendors, Architect, Commissioning Agent, and Owner. The commissioning team shall be comprised of the following:

1. Contractor
 - a. Project Manager
 - b. Test Engineer
1. Subcontractors
 - a. As required by the prime Contractor
2. Commissioning Agent
 - a. Project Manager
 - b. Project Engineers
3. Owner Representative(s) – Engineering, EH&S, etc.
4. Architect
 - a. Architect
 - b. Mechanical Consultant
 - c. Electrical Consultant

1.04 SUBMITTALS

- A. General: Submit the following in accordance with Conditions of the Contract and Division 01 Specification Sections.
- B. Commissioning plan: Submit commissioning plan to the Owner's Representative for review and approval by the Architect and Commissioning Agent within 90 calendar days of Notice to Proceed.
- C. Commissioning schedule: Submit commissioning schedule to the Owner's Representative for review and approval by the Architect and Commissioning Agent within 90 calendar days of Notice to Proceed.
- D. Start-up plan: For each piece of equipment or system for which formal start-up is specified elsewhere in this division, submit a start-up plan to the Owner's Representative for review and approval by the Architect and Commissioning Agent. Obtain approval of the plan prior to beginning -activities. The plan should include the following:
 1. Start-up schedule
 2. Names of firms/individuals required to participate
 3. Detailed start-up procedures

4. Start-up data forms
- E. Test equipment identification list: For each instrument, sorted according to intended use, submit a list containing the following information to the Owner's Representative for review and approval by the Architect and Commissioning Agent:
 1. Manufacturer
 2. Model number
 3. Serial number
 4. Calibration certification
 5. Range
 6. Accuracy
 7. Resolution
 8. Intended use
 - F. Operations and maintenance manuals: Submit to Owner's Representative prior to the start of training.
 - G. Start-up procedures: Submit start-up procedures for equipment for which formal start-up is specified elsewhere to the Owner's Representative for review and approval by the Architect and Commissioning Agent. These procedures will be reviewed for technical depth, clarity of documentation, and completeness.
 - H. Start-up data forms: Submit start-up data forms for equipment for which formal start-up is specified elsewhere, to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
 - I. Testing, Adjusting, and Balancing (TAB) data forms: Submit testing, adjusting, and balancing (TAB) data forms to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
 - J. Testing, Adjusting, and Balancing (TAB) procedures: Submit written testing, adjusting, and balancing (TAB) procedures to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
 - K. Testing, Adjusting, and Balancing (TAB) report: Submit written testing, adjusting, and balancing (TAB) report to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
 - L. Functional performance test procedures: Submit functional performance test procedures for functional performance tests specified elsewhere to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
 1. Each procedure shall have a unique alphanumeric designator.
 2. The same procedure may be applied to multiple identical pieces of equipment or systems.

3. Procedures shall reference the applicable specification section upon which the procedure is based.
 4. These procedures will be reviewed for technical depth, clarity of documentation, compliance with "Acceptance Criteria" specified elsewhere, and completeness.
 5. Identify the value for all setpoints and inputs, positions of adjustable devices, valves, dampers and switches.
 6. Identify the range of acceptable results for each condition tested.
 7. FPT procedures shall be detailed test instructions, written with sufficient step-by-step information to allow a test to be repeated under identical conditions with repeatable results.
- M. Functional performance test data forms: Submit functional performance test data forms for equipment for which functional performance tests are specified elsewhere to the Owner's Representative for review and approval by the Architect and Commissioning Agent.
1. Identify each functional performance test data form by a unique designator, consisting of the applicable functional performance test procedure designator followed by a dash and digit suffix to distinguish multiple repetitions of the same procedure.
 2. Include space to record the following:
 - a. Description of the procedure
 - b. Whether the form is for a retest of a failed procedure
 - c. Identification and location of the equipment being tested
 - d. Identification of instrumentation used, by serial number
 - e. Observed conditions at each step of the procedure
 - f. "Acceptable results" as specified elsewhere
 - g. Date of the test
 - h. Names of technicians performing the procedure
 - i. Name and signature of the Test Engineer
 - j. Name and signature of the Commissioning Agent or Owner-designated witness. Signature of witness shall only indicate concurrence with reported results and observations. Acceptance of the results will be reported separately by the Commissioning Agent after review of the FPT data forms.
 3. The FPTPs shall identify:
 - a. Who needs to be in attendance for the tests including subcontractors, owner, regulatory agencies, etc. and
 - b. The sequence of the tests to be performed.
 4. Draft FPTPs shall be distributed to the commissioning agent, owner, and EH&S. Allow for a two week review period prior to scheduling any tests.

- N. Functional performance test deficiency report forms: Submit functional performance test deficiency report forms to the Owner's Representative for review and approval by the Architect and Commissioning Agent. Include space to record the following:
1. Associated functional performance test data form number
 2. Date of test
 3. Name of person reporting the deficiency
 4. Description of the observations associated with the failure of the test
 5. Cause of the failure if apparent at the time of the test
 6. Date and description of corrective action taken
 7. Name and signature of person taking corrective action
 8. Schedule for retest

1.05 COMMISSIONING PLAN

- A. Develop a commissioning plan to identify how commissioning activities will be integrated into general construction and trade activities. The plan is the key means for the Test Engineer to inform all parties as to how each system functions, independently and with respect to other systems. The plan shall be updated regularly and redistributed to the commissioning team for review and comment. The intent of this plan is to evoke questions, expose issues, and resolve them with input from the entire commissioning team early in construction. The commissioning plan shall identify how commissioning responsibilities are distributed.
1. Include an organizational chart showing lines of communication and authority of the Test Engineer relative to key General Contractor positions and to key subcontractors.
 2. Identify who will be responsible for producing the various procedures, reports, Owner notifications, and forms required in this division.
 3. Include the commissioning schedule.
 4. Describe the test/acceptance procedure.
 5. Identify which subcontractors will participate in each of the tests.
 6. Identify instrumentation required for each test.
 7. Identify who will provide instrumentation for each test.
 8. Operational description: This shall include, for example, the design criteria, design intent, code requirements, specifics of the equipment to be provided, sequences of operation, operating priorities, protocols, etc.

1.06 SCHEDULE

- A. Integrate functional performance testing and commissioning requirements into the Critical Path Method (CPM) master construction schedule. Commissioning scheduling is the responsibility of the Contractor.

- B. Commissioning of systems shall proceed per the criteria established in the specific sections that follow, with activities to be performed on a timely basis. Commissioning of systems may proceed prior to final completion of systems. The Test Engineer must be available to respond promptly to avoid delay to the CPM schedule.
- C. Problems observed shall be addressed immediately, in terms of notification to responsible parties and actions to correct deficiencies.

1.07 COORDINATION WITH COMMISSIONING AGENT

- A. The Commissioning Agent will witness all start-up and test activities specified in this division. The Owner's Representative will designate witnesses and alternates for each activity.
- B. Notify the Owner's Representative in writing of the date, time, location, and anticipated duration of start-up and test activities as required in "Schedule" above.
- C. Provide written timely notice to Owner's Representative of any changes in date, time, location, or anticipated duration of start-up and test activities. For the purpose of this paragraph, written notice shall be received by Owner's Representative a minimum of 72 hours in advance to be considered timely notice.
- D. Contractor shall reimburse Owner for actual costs incurred by the Owner as the result of failure to provide timely notice, per preceding paragraph, of changes in date, time, location, or anticipated duration of start-up and test activities.
- E. Obtain the signature of designated witness on all data forms. If the witness is unavailable at the scheduled time and location of the activity, so note, and proceed per schedule without the witness.

PART 2 - PRODUCTS

2.01 TEST EQUIPMENT

- A. Provide industry standard test equipment required for performing the tests specified herein.
- B. Instrumentation shall meet the following standards:
 - 1. Be of sufficient quality and accuracy to test and measure system performance within the tolerances required to determine adequate performance.
 - 2. Be calibrated on the manufacturer's recommended intervals with calibration tags permanently affixed to the instrument being used.
 - 3. Be maintained in good repair and operation condition throughout the duration of use on this project.
 - 4. Be recalibrated/repared if dropped or damaged in any way since last calibrated.
- C. For all temperature measurements including air, liquids, and surfaces of pipes and components using appropriate probes:
 - 1. Range: Minimum +14 °F to 248°F

- a. Type: Thermometer, Digital Electronic
 - b. Minimum accuracy: +/- .5°F
 - c. Calibration Interval: Per manufacturer instruction, not to exceed every 12 months
- D. For Hydronic pressure and differential pressure measurement instruments:
- 1. Range: 0 to 30 psi, 0 to 60 psi and 0 to 200 psi
 - a. Type: Calibrated Test Gauges, 3 inch, or electronic digital device (TSI or similar) meeting accuracy and calibration interval requirements
 - b. Minimum accuracy: 2% of scale (Gauge), 3% of reading (electronic)
 - c. Calibration interval: Per manufacturers instruction, not to exceed every 12 months
 - d. Note: Use lowest range instrument or scale.
- E. Air pressure measurement instruments:
- 1. Range: 0 to 1 inch w.c., 0 to 4 inch w.c., 0 to 10 inch w.c.
 - a. Type: Use properly leveled and zeroed manometer, Magnehelic or electronic instrument meeting accuracy requirements.
 - b. Minimum accuracy for electronic devices: 2% of reading (Magnehelic), 3% of reading (electronic)
 - c. Calibration Interval for electronic devices: Per manufacturer's instructions, not to exceed every 12 months
 - d. Note: Use lowest range instrument or scale.
- F. Provide a list of all test equipment used in commissioning. Show manufacturer, model number, serial number and date of most recent calibration. Provide an updated report if any instruments are added to the commissioning while the testing is in progress.

2.02 REPORTS

- A. Test, adjust and balance (TAB) progress reports: After TAB activities have begun, submit weekly test, adjust and balance (TAB) progress reports to the Owner's Representative. Identify the following:
- 1. Systems or subsystems for which preliminary balancing is complete
 - 2. Systems or subsystems for which final balancing is complete
 - 3. Status of deficiencies and balancing problems encountered, including corrective actions taken
 - 4. Updated schedule of remaining TAB activities
- B. Installation verification audit: Prior to start-up, submit to the Owner's Representative for review and approval by the Architect and Commissioning Agent a report of installation verification audit

activities. Identify equipment and components verified, deficiencies noted, corrective action taken, and the dates and initials of the persons making the entries.

- C. Start-up deficiency report: Within five days following start-up of each system or equipment, submit to the Owner's Representative start-up deficiency report forms. Identify systems and/or equipment started up, deficiencies noted, corrective action taken, and the dates and initials of the persons making the entries.
- D. Functional performance test deficiency reports: At the end of each day in which functional performance tests are conducted, submit to the Owner's Representative functional performance test deficiency report forms for tests in which acceptable results were not achieved during the day.
 - 1. Identify tests for which acceptable results were not obtained by test number and description, and equipment identification and location. Briefly describe observations about the performance which was associated with failure to achieve acceptable results. Identify the cause of failure if such is apparent.
 - 2. When corrections have been completed, update the functional performance test deficiency report forms. Identify corrective action taken and the dates and initials of the persons making the entries.
 - 3. Identify the schedule for retesting.

PART 3 - EXECUTION

3.01 BASIS OF DESIGN DOCUMENTATION

- A. Edit and update basis of design narratives provided by the Owner's Representative (Consultant). Incorporate the effect of approved substitution requests, change orders, and responses to RFIs which change the information in the Architect's basis of design narratives. "Basis of design" includes design criteria and operations descriptions for systems itemized in Paragraph 3.02.
- B. Design criteria shall include design conditions for each space as follows:
 - 1. Indoor dry bulb temperature
 - 2. Indoor relative humidity
 - 3. Outdoor dry bulb temperature
 - 4. Outdoor wet bulb temperature
 - 5. Occupancy, hours, and degree of activity
 - 6. Lighting and miscellaneous power
 - 7. Ventilation -- recirculation and outside air
 - 8. Internal loads
 - 9. Special loads
 - 10. Insulating R-values for roof, wall, glass, etc.
 - 11. Percentage of glass -- fenestration

12. Type of glass, including coatings and solar coefficients
 13. Building pressurization and infiltration
 14. Building mass
 15. Code requirements and impact on criteria
 16. Air quality design criteria, i.e. ASHRAE 62-89
 17. Noise criteria
 18. Fire and life safety
 19. Energy efficiency and cost
 20. Maintainability
- C. Operations description includes design intent, basic system type, major components, interrelation of components, capacity and sizing criteria, redundancy, diversity, automatic temperature control and sequence of operation, intended operation under all seasonal loads, changeover procedures, part-load strategies, occupied/unoccupied modes of operation, design setpoints of control systems with permissible adjustments, operation of system components in life-safety modes, energy conservation procedures, and any other engineered operational mode of the systems.

3.02 ONE-LINE DIAGRAMS

- A. Provide one-line diagrams: One-line diagrams are intended to support narrative system descriptions and the overall commissioning process. Depending on the system in question, the following procedures for developing the one-line diagrams are to be employed:
1. Update: AutoCAD-based one-line diagrams provided by the Architect for the following systems [RC1]. Some revisions may be required to match the desired format for commissioning documents.
 - a. Hot Water Heating
 - b. Domestic Water
 - c. Steam and Condensate
 - d. Chilled Water Systems
 - e. Condenser Water Systems
 - f. Supply Air Systems
 - g. Return Air Systems
 - h. Exhaust Air Systems
 2. Update and revise vendor supplied AutoCAD-based shop drawings; revise as required to match the format for commissioning documents. This method shall be employed for the following systems:
 - a. Environmental Control System
 - b. Energy Management Control

- c. Fire Alarm/Smoke Evacuation/Life Safety Graphics

3.03 COMMISSIONING PROCEDURE

- A. Sequence of testing: Commissioning shall proceed from lower to higher levels of complexity. For each discrete subsystem or system, testing at the lower level shall be completed prior to starting the next higher level of tests. In general, the order of testing, from lowest to highest is as follows:
 - 1. Static tests (e.g. duct leakage tests)
 - 2. Component functional performance tests (i.e. motors, actuators and sensors) and start-up
 - 3. Balancing
 - 4. System functional performance tests
 - 5. Intersystem functional performance tests
- B. Retesting: Repeat, at no additional cost to the Owner, the complete functional test procedure for each test in which acceptable results are not achieved. Repeat tests until acceptable results are achieved. Compensate the Owner for direct costs incurred as the result of tests repeated to achieve acceptable results. Fill out a new functional performance test data form for each retest.
- C. Correction of deficiencies
 - 1. Correct functional performance test deficiencies promptly and schedule retest.
 - 2. Corrections during functional performance tests are generally prohibited to avoid consuming the time of personnel waiting for the test, but not involved in making the correction. Exceptions will be allowed if the cause of the failure is obvious and corrective action can be completed in less than five minutes. If corrections are made under this exception, the failure shall be noted on the functional performance test data form. A new functional performance test data form, marked "retest," shall be initiated after the correction has been made. The entire functional performance test procedure shall be repeated.
- D. Owner witness: Commissioning Agent shall provide no labor or materials in the commissioning process. The only function of the Commissioning Agent shall be to observe and comment on the progress and results of commissioning.
 - 1. Provide access to permit the Commissioning Agent to directly observe the performance of the equipment being tested.
 - 2. Provide ladders, scaffolding, and staging as required to permit the Commissioning Agent to directly observe the performance of the equipment being tested.
 - 3. Notify the Owner's Representative of commissioning schedule changes at least 48 hours in advance if a Commissioning Agent will be involved.

3.04 INSTALLATION VERIFICATION

- A. During construction, observe the work of the prime Contractor and subcontractors to assure that all installations are being made in accordance with the intent of the contract documents.

- B. Before system start-up begins, conduct a final installation verification audit. The Contractor shall be responsible for completion of all work, including change orders and punch list items, to the satisfaction of the Owner's Representative. The audit shall include, but not be limited to, a check of the following:
1. Piping specialties, including balance, control, and isolation valves
 2. Ductwork specialty items, including turning devices; balance, fire, smoke and control dampers; and access doors
 3. Control sensor types and locations
 4. Identification of piping, valves, starters, gauges, thermometers, etc.
 5. Documentation of prestart-up tests performed, including manufacturer's factory tests
 6. Accessibility to equipment in 1-3 above
 7. Verification of final programmed VFD settings.
- C. If any work is found to be incomplete, inaccessible, incorrect, or non-functional, make note of deficiencies, and correct deficiencies before system start-up work proceeds.

3.05 SYSTEM START-UP

- A. Develop a start-up plan. Commence with system start-up after approval has been given to the start-up plan and the pre-start-up inspection has been completed by the Test Engineer. The Test Engineer shall witness system start-up and list all system and equipment deficiencies noted during start-up. The Contractor shall take corrective action on all system deficiencies noted and demonstrate to the Test Engineer suitable system operation. Notify Architect of start-up activities' schedule at least five working days in advance. Owner's Representative and Commissioning Agent will physically witness start-up procedures. Test Engineer shall obtain signature of the Owner's Representative and Commissioning Agent indicating successful start-up.

3.06 START-UP DEFICIENCY LISTS

- A. Prepare Start-up Deficiency List forms to report deficiencies discovered in conjunction with system start-up. Start-up deficiency forms shall indicate the system being started-up, the location and identification of the deficient equipment/material, date of observation; initials of the observer; observed deficiency; date of correction; initials of person making the correction; and corrective action taken.
- B. Issue Start-up Deficiency Report Forms to the Contractor for corrective action, and to the Owner's Representative for follow-up. The Contractor shall advise the Test Engineer and Owner's Representative when all start-up deficiency list items have been corrected.
- C. Complete all point-to-point testing prior to start of Test, Adjust and Balance (TAB).

3.07 TEST, ADJUST, AND BALANCE (TAB)

- A. Perform and coordinate air and hydronic balancing. Advise the TAB firm when systems are complete and ready for balancing. Start TAB as early as possible following system start-ups and

component functional performance tests, in order to be essentially complete prior to system functional performance tests. Coordinate TAB activities with other construction schedule activities.

- B. Verify the accuracy of the TAB work prior to commencing any FPT activities which may be adversely affected by improper balancing.

3.08 FUNCTIONAL PERFORMANCE TEST PROCEDURES

- A. Develop start-up procedures and functional performance test procedures and documentation to be used. Personnel experienced in the technical aspects of each system to be commissioned shall be engaged if necessary to augment the expertise of the Test Engineer. Include functional performance test procedures and functional performance test data sheets for each system based upon actual system's configuration. Emphasis shall be placed on testing procedures which will conclusively determine actual system performance and compliance with the design.
- B. Test procedures shall fully describe system configuration and steps required for each test, appropriately documented so that another party can repeat the tests with virtually identical results.
- C. Acceptance test procedures must confirm the performance of systems to the extent of the design intent and applicable code under which the project was permitted. When a system is accepted, the Commissioning Agent must be assured that the system is complete, works as intended, is correctly documented, and that the Owner's staff is trained in the operation and maintenance of the system.
- D. The majority of mechanical equipment requires integral safety devices to stop/prevent equipment operation unless minimum safety standards or conditions are met. This could include adequate oil pressure, proof-of-flow, non-freezing conditions, maximum head pressure, etc. Functional performance test procedures shall demonstrate the actual performance of safety shutoffs in a real or closely simulated condition of failure.
- E. Systems may include safety devices and components that control a variety of equipment operating as a system. Interlocks may be hard-wired or installed via software. Functional performance test procedures shall demonstrate these interlocks.
- F. Inform appropriate subcontractor(s) and vendor(s) before commissioning is started as to what the test and expected results will be. Because some test results and interpretations may not become evident until the actual tests are performed, all participants should have a reasonable understanding of the requirements. The commissioning plan must address the requirements and be distributed to all participants involved with that particular system.

3.09 REVIEW SOFTWARE DOCUMENTATION

- A. Review, prior to installation of control devices, vendor/contractor-provided detailed BAS software documentation. This includes obtaining BAS program documentation, a review of the programming approach, interface with other systems (e.g. lighting, fire alarm, security, clock, emergency generator monitoring, sump pumps, distributed and mechanical utility metering), and a review of the specific software routines as applied to this project. Discrepancies in programming approaches will be resolved to provide the Owner with the most appropriate, simple, and straightforward approach to software routines.
- B. Provide copies of all of the preceding material, including electronic copies of all control system software to the Owner's Representative, so that Owner's technical staff can simulate system operation and troubleshoot the software.

3.10 TRAINING

- A. Prepare and submit for approval a training plan. Training plan shall include for each training session the following:
 - 1. Dates, start and finish times, and locations
 - 2. Outline of the information to be presented
 - 3. Names and qualifications of the presenters
 - 4. List of texts and other materials required to support training
- B. Obtain assistance from appropriate subcontractors and vendors to provide training for the Owner's operations staff.
- C. Provide videotape documentation of training of the Owner's staff for each system. Training will be in a classroom setting with the appropriate schematics, handouts, and audio/visual training aids.
- D. Catalog training videotapes and deliver to the Owner with the O&M manuals.
- E. Host each training session:
 - 1. Provide program overview and curriculum guidance.
 - 2. Obtain signatures of attendees on a sign-in list.
- F. Equipment vendors provide training on the specifics of each system and philosophy, troubleshooting, and repair techniques as specified in the relevant sections of this specification.
- G. Installation subcontractors provide training on peculiarities specific to this project and job specific experience as specified in the relevant sections of this specification.
- H. Review record documents to verify accuracy.

3.11 FUNCTIONAL COMPLETION

- A. The Commissioning Agent will review Contractor's records of completion of Commissioning requirements. Upon receiving evidence of satisfactory completion of Functional Completion requirements in Section 01700, the Test Engineer will submit to the Owner a recommendation to accept Functional Completion.

3.12 EXCLUSIONS

- A. The Owner's Representative and Commissioning Agent are not responsible for construction means, methods, job safety, or any management function related to commissioning on the job site.
- B. The Contractor shall provide all technician services requiring tools or the use of tools, to test, adjust or otherwise bring equipment into a full operational state.

END OF GUIDE SPECIFICATION
COMMISSIONING: GENERAL REQUIREMENTS

GUIDE SPECIFICATION

The following specification is intended as a guide only. The Consultant shall modify the specifications to meet the project needs in consultation with the Owner.

MECHANICAL – COMMISSIONING: FUNCTIONAL PERFORMANCE TESTING

PART 1 - GENERAL

1.01 DESCRIPTION

- A. The purpose of functional performance testing (FPT) is to assure the Owner that all work has been completed as specified and that systems are functioning in the manner intended, within the limits of the design and the contract documents. It will serve as a tool to minimize post-occupancy systems operational difficulty or failure. It will assist operations staff familiarization and training with new systems. It will also be used to develop test protocols and record associated test data in an effort to advance the building systems from a state of substantial completion to full dynamic operation.

Functional performance testing will commence as systems are brought to substantial completion and will be done on a system-by-system basis. The results of these tests will be documented and handed over to the Commissioning Agent and Owner for final system acceptance.

- B. Substantial Completion requires that:
1. All testing be complete and approved.
 2. O&M manuals are complete (not in process).
 3. All training is complete.

1.02 SYSTEMS TO BE TESTED

- A. FPT will be performed on the following systems:
1. HVAC
 - a. Air Handling System
 - b. Exhaust System
 - c. Lab Air System Terminal Equipment
 - d. Heating Water System (pumps, coils)
 - e. Central Cooling Water System (pumps, coils)
 - f. Process Chilled Water System (chillers, towers, pumps)
 - g. Verification of room noise criteria
 2. Controls
 - a. Environment Control System
 - b. Energy Conservation System

- c. Sensors
 - d. Setpoints and calibration
 - e. Control loop strategy and function
3. Life Safety and Building Protection
- a. Smoke and fire control systems and components
 - b. Stair and elevator pressurization systems

PART 2 - PRODUCTS

Not applicable to this section.

PART 3- EXECUTION

3.01 GENERAL

- A. The Contractor and subcontractors shall be responsible for performing all procedures presented in the specification and contract drawings, unless otherwise specified. The Test Engineer and Commissioning Agent will witness system start up and functional performance for all systems listed in this division.

3.02 FUNCTIONAL PERFORMANCE TESTING

- A. Functional performance testing begins after the systems have been completed by the contractors, the system description and training sessions have been completed, and the O&M manuals have been completed.
- B. The objective of functional performance testing is to advance the building systems from a state of substantial completion to full dynamic operation in accordance with the specified design requirements and design intent.
- C. The Test Engineer shall attain this objective by developing individual system-testing protocols which, when implemented by the Contractor, will allow the Test Engineer to observe, evaluate, identify deficiencies, recommend modifications, tune, and document the systems and systems' equipment performance over a range of load and functional levels.
- D. The UW has examples of test procedure check-off sheets. They are not tailored to this facility. The Test Engineer shall use these examples as the format for developing test procedure check-off sheets for all equipment and systems specific to this facility and submit them to the Commissioning Agent and Owner for approval.

END OF GUIDE SPECIFICATION
COMMISSIONING: FUNCTIONAL PERFORMANCE TESTING

GUIDE SPECIFICATION

The following Guide Specification is intended to be modified and included in the construction contract documents. Items to be modified will be decided by consultation involving the Project Manager, the A/E, and Campus Engineering. The A/E is expected to modify this and other specifications as necessary to accurately reflect commissioning requirements based upon specific conditions of the project.

MECHANICAL – COMMISSIONING: FACILITY START-UP

PART 1 - GENERAL

1.01 SCOPE OF THE WORK

- A. The purpose of this section is to specify Division 15 responsibilities and participation in the commissioning process.
- B. Commissioning is the responsibility of the Contractor (including subcontractors and vendors). The Contractor is responsible to provide all scheduling, coordination and support required for start-up, testing, and commissioning (see Section 01450). Commissioning Section is intended to provide an indication of the tests which must be performed by the Contractor prior to and including verification by the Owner's Representative. The commissioning process requires Division 15 participation to ensure all portions of the work have been completed in a satisfactory and fully operational manner.
- C. Work of Division 15 includes the following:
 - 1. Start-up and testing of the mechanical equipment and systems
 - 2. Assistance in testing, adjusting and balancing
 - 3. Operating equipment and systems as required for commissioning tests
 - 4. Providing qualified personnel for participation in commissioning
 - 5. Providing equipment, materials, and labor necessary to correct deficiencies found during the commissioning process which fulfill contract and warranty requirements
 - 6. Providing operation and maintenance information and as-built drawings to the Contractor
 - 7. Providing assistance to the Contractor to develop and edit system operation descriptions
 - 8. Providing training for the systems specified in this division with coordination by the Contractor and Owner's Representative

1.02 RELATED WORK

- A. All start-up and testing procedures and documentation requirements specified within Division 15
- B. All Division 17 commissioning procedures that require participation of Division 15
- C. Cooperate with the Testing, Adjusting and Balancing (TAB) firm in the following manner:
 - 1. Allow sufficient time before final commissioning dates so that testing, adjusting and balancing can be accomplished.

2. Put all heating, ventilating, and air conditioning equipment and systems into full operation and continue the operation during each working day of testing, adjusting, balancing and commissioning.
3. Provide labor and material to make corrections when required, without undue delay.
4. Include the cost of exchange sheaves and belts as may be required by the TAB firm.
5. Provide test holes in ducts and plenums where directed or necessary for pitot tubes to take air measurements and to balance the air systems. Test holes shall be provided with an approved removable plug or seal. At each location where ducts or plenums are insulated, test holes shall be provided with an approved extension with plug fitting.
6. Provide pressure and temperature taps as indicated on construction documents in locations as required by the TAB firm to adequately test and/or balance the hydronic systems.

PART 2 - PRODUCTS

2.01 TEST EQUIPMENT

- A. Provide test equipment as necessary for start-up and commissioning of the mechanical equipment and systems. The TAB firm will provide the test equipment required to perform TAB services.
- B. Proprietary test equipment required by the mechanical equipment manufacturer, whether specified or not, shall be provided by the manufacturer of the equipment. Manufacturer shall demonstrate its use and assist the Contractor in the commissioning process.

PART 3 - EXECUTION

3.01 WORK PRIOR TO COMMISSIONING

- A. Complete all phases of work so each system can be started, tested, adjusted, balanced, and otherwise commissioned. Division 15 has primary start-up responsibilities with obligations to complete systems, including all sub-systems, so they are fully functional. This includes the complete installation of all equipment, materials, pipe, duct, wire, insulation, controls, etc., per the contract documents and related directives, clarifications, change orders, etc.
- B. A commissioning plan will be developed by the Test Engineer and approved by the Owner's Representative.
 1. Division 15 is obligated to assist the Contractor in preparing the commissioning plan by providing all necessary information pertaining to the actual equipment and installation.
 2. If system modifications/clarifications are called for in the contractual requirements of this and related sections of work, they will be made at no additional cost to the Owner.
 3. If Contractor-initiated system changes have been made that alter the commissioning process, the Contractor will notify the Owner's Representative for approval.
- C. Specific pre-commissioning responsibilities of Division 15 are as follows:

1. Factory start-up services for the following items of equipment: Air-handling equipment, heating equipment, cooling equipment, plumbing equipment, pumps, chillers, cooling towers, variable speed drives.
2. Normal start-up services required to bring each system into a fully operational state include the following:
 - a. Cleaning, filling, purging, leak testing, alignment, lubrication, motor rotation check, control sequences of operation, full and part load performance, etc.
 - b. The TAB firm will not begin the TAB work until each system is complete, including normal contractor start-up.
 - c. The Contractor will not begin the commissioning process until each system is complete, including normal contractor start-up, and the TAB work has been completed.
3. Commissioning is intended to begin upon completion of a system but may proceed prior to the completion of systems, or sub-systems, and will be coordinated with the Contractor. Start of commissioning before system completion will not relieve Division 15 from completing those systems as per the schedule.
4. Red-lined as-built drawings shall be available during commissioning.

3.02 PARTICIPATION IN COMMISSIONING

- A. Provide skilled technicians to start up all systems within Division 15.
 1. These same technicians shall be made available to assist the Contractor and Commissioning Agent in completing the commissioning program as it relates to each system and their technical specialty.
 2. Work schedules, time required for testing, etc., will be requested and coordinated by the Contractor.
 3. Division 15 will ensure that qualified technician(s) are available and present during the agreed-upon schedules and for sufficient duration to complete the necessary tests, adjustment, and problem resolutions.
- B. System problems and discrepancies may require additional technician time which shall be made available for the subsequent commissioning periods until required system performance is obtained.
- C. The Owner's Representative reserves the right to judge the appropriateness and qualifications of the technicians relative to each item of equipment or system. Such qualifications include expert knowledge relative to the specific equipment involved, adequate documentation and tools to service/commission the equipment, and an attitude/willingness to work with the Contractor to get the job done.

3.03 WORK TO RESOLVE DEFICIENCIES

- A. In some systems, misadjustments, misapplied equipment and/or deficient performance under varying loads will result in additional work being required to commission the systems. This work will be completed under the direction of the Owner's Representative and the Architect, with input from the Contractor and equipment supplier. Whereas all members will have input and the opportunity to

discuss the work and resolve problems, the Architect will have final jurisdiction on the work needed to achieve performance.

- B. Corrective work shall be completed in a timely fashion to permit timely completion of the commissioning process.
 - 1. Experimentation to render system performance will be permitted.
 - a. If the Architect deems the experimentation work to be ineffective or untimely as it relates to the commissioning process, the Architect will notify the Owner indicating the nature of the problem, expected steps to be taken, and the deadline for completion of activities.
 - b. If deadlines pass without resolution of the problem, the Owner reserves the right to obtain supplementary services and/or equipment to resolve the problem.
 - c. Costs incurred to solve the problem in an expeditious manner will be the Contractor's responsibility.

3.04 SEASONAL COMMISSIONING AND OCCUPANCY VARIATIONS

- A. Seasonal commissioning pertains to testing under full-load conditions during peak heating and peak cooling seasons, as well as part-load conditions in the spring and fall.
 - 1. Initial commissioning will be done as soon as contract work is completed regardless of season.
 - 2. Commissioning under conditions representing other than the current season may be undertaken at a later time by the Test Engineer and Commissioning Agent.
 - 3. Discrepancies discovered with the Contractor's equipment or workmanship will be handled as warranty items.
- B. Commissioning may be required under conditions of minimum and/or maximum occupancy or use.
 - 1. All equipment and systems affected by occupancy variations will be tested and commissioned at the minimum and peak loads to observe system performance.
 - 2. The Contractor will be responsible to participate in the occupancy-sensitive testing of systems to provide verification of adequate performance.
 - 3. If such occupancy is not available within the contract period, related commissioning may be undertaken at a later time by the Owner's Representative; the Contractor will not be expected to participate in this later commissioning.
 - 4. Discrepancies discovered with the Contractor's equipment or workmanship will be handled as warranty items.

3.05 RETESTING AND RECOMMISSIONING

- A. Any fault in material or in any part of the installation revealed by commissioning tests shall be investigated, replaced, or repaired by the Contractor, and the same test repeated at the Contractor's expense until no fault appears.

3.06 TRAINING

- A. Participate in the training of the Owner's engineering and maintenance staff, as required in Divisions 1 and 17, on each system and related components. Training, in part, will be conducted in a classroom setting, with system and component documentation, and suitable classroom training aids.
- B. Training will be conducted jointly by the Contractor, the Design Engineers, and the equipment vendors. The Contractor will be responsible for highlighting system peculiarities specific to this project.

3.07 MISCELLANEOUS SUPPORT

- A. Division 15 shall remove and replace covers of mechanical equipment, open access panels, etc., to permit Contractor, Architect and Owner's Representative to observe equipment and controllers provided. Furnish ladders and flashlights as necessary.

END OF GUIDE SPECIFICATION
COMMISSIONING: FACILITY START-UP