

COMMISSIONING GUIDE SPECIFICATIONS

SECTION 15997 MECHANICAL TESTING REQUIREMENTS

Spec writer:

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

Spec Writer: A/E and design phase CA should:

1. Review the functional test requirements and add or change requirements, as necessary, for the current project. Pay particular attention to smaller equipment (small AHU, RTUs etc.) which will not warrant the same rigor as larger units portrayed here currently. Delete requirements for equipment not existing in the current project.
2. Make sure that every piece of mechanical equipment or system has a unique test requirement or is listed as a component of a system with testing requirements given. Use the format of this section for new test requirements.
3. Include intersystem test requirements where significant interactions or interlocks exist between systems.
4. Consider the adequacy of the Guide Specification Acceptance Criteria and add detail where necessary.

PART 1 - GENERAL

1.1. INCLUDED SYSTEMS AND EQUIPMENT

- A. The following is a list of the equipment and system test requirements included in this section:
1. Air handler system
 2. Boiler system
 3. Building automation system
 4. Chiller system
 5. Cooling tower
 6. Exhaust fans
 7. Indoor air climate control--misc. systems
 8. Indoor air quality (IAQ)
 9. Packaged DX air conditioning or heat pump
 10. Service hot water system
 11. Terminal unit
 12. Test and balance (TAB) work

1.2 DESCRIPTION

- A. This section specifies the functional testing requirements for Division 15 systems and equipment. From these requirements, the Commissioning Authority (CA) shall develop step-by-step procedures to be executed by the Subs or the Commissioning Authority. The general functional testing process, requirements and test method definitions are described in Section 17100. The

test requirements for each piece of equipment or system contain the following:

1. The contractors responsible to execute the tests, under the direction of the CA.

Spec Writer: In some commissioning scenarios on simpler equipment, the CA actually performs hands-on testing without the assistance of any contractors. When this is the case, it should be specifically mentioned in the testing requirements for each type of equipment, so the contractors do not bid work they are not responsible for.

In the example language below, it is assumed that the CA will not perform any significant equipment testing without some contractor assistance, other than the service water heating system.

2. A list of the integral components being tested.
3. Prefunctional checklists associated with the components.
4. Functions and modes to be tested.
5. Required conditions of the test for each mode.
6. Special procedures.
7. Required methods of testing.
8. Required monitoring.
9. Acceptance criteria.
10. Sampling strategies allowed.

1.3 PREREQUISITES

The following applicable generic prerequisite checklist items are required to be listed on each written functional test form and be completed and checked off by CA prior to functional testing.

- ___ All related equipment has been started up and start-up reports and prefunctional checklists submitted and approved ready for functional testing:
- ___ All control system functions for this and all interlocking systems are programmed and operable per contract documents, including final setpoints and schedules with debugging, loop tuning and sensor calibrations completed.

Controls Contractor Signature or Verbal

Date

- ___ Piping system flushing complete and required report approved.
- ___ Water treatment system complete and operational.
- ___ Vibration control report approved (if required).
- ___ Test and balance (TAB) complete and approved for the hydronic system.
- ___ All A/E punchlist items for this equipment corrected.
- ___ These functional test procedures reviewed and approved by installing contractor.
- ___ Safeties and operating ranges reviewed by the CA.
- ___ Test requirements and sequences of operation attached.
- ___ Schedules and setpoints attached.
- ___ False loading equipment, system and procedures ready.
- ___ Crankcase heaters have been on long enough for immediate startup.
- ___ Sufficient clearance around equipment for servicing.
- ___ Record of all values for pre-test setpoints changed to accommodate testing has been made and a check box provided to verify return to original values (control parameters, limits, delays, lockouts, schedules, etc.).
- ___ Other miscellaneous checks of the prefunctional checklist and start-up reports completed successfully.

1.4 MONITORING

- a. Monitoring is a method of testing as a stand-alone method or to augment manual testing.

- b. All points listed in the required monitoring section of the test requirements which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. At the option of the CA, some control system monitoring may be replaced with datalogger monitoring. At the CA's request, the controls contractor shall trend up to 20% more points than listed herein at no extra charge.
- c. Hard copies of monitored data must be in columnar format with time down the left column and at least 5 columns of point values on the same page.
- d. Graphical output is desirable, and will be required for all output, if the system can produce it.

PART 2 - PRODUCTS

-- NOT APPLICABLE --

PART 3 - EXECUTION

1. AIR HANDLER UNITS (AHU)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment as needed.
2. CA: to witness, direct and document testing.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

- | | |
|---|-----------|
| 1. AHU and components (fans, coils, valves, ducts, VFD) | PC- _____ |
| 2. Heat recovery coil, humidifier or evaporative cooling sections | PC- _____ |

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are an addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both ³ | <u>Required Seasonal Test</u> ¹ |
|--|--|--|
| General | | |
| 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Mixed & supply air, & reset temperature control functions. | Both | |
| 3. Economizer functions. | Both | Cooling |
| 4. SF, RF and exhaust fan interlocks. | Either | |
| 5. No CCV flow when there is HCV flow. | Both | |
| 6. CCV & HCV modulation & positive shutoff (no leak-thru). | Manual | |
| 7. Duct static pressure (SP) control. | Both | |
| 8. Return or exhaust fan tracking and building SP. | Monitoring | |
| 9. VFD (or inlet vanes) operation on SF and RF: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, constancy of static pressure, verification of program settings, alarms, etc. | Both | ² |
| 10. Damper interlocks and correct modulation in all modes, including smoke and fire dampers. | Manual | |
| 11. Temperature difference across HC & CC per specifications. | Manual | |
| 12. Verification of minimum OSA control through varying VAV box positions. | Either | ² |
| 13. Heating and cooling coils freeze protection. | Manual | ² |
| 14. Branch duct control damper control. | Manual | |
| 15. Night low limit, morning warmup cycle. | Either | |
| 16. Heat recovery operation. | Monitoring | |
| 17. Verify TAB reported SF cfm with control system reading. | Manual | ² |
| 18. All alarms (low limits, high static, etc.). | Manual | |
| 19. Heating and cooling coil capacity test, optional. | Manual | Design |

SECTION 15997 – 5
MECHANICAL TESTING REQUIREMENTS

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both ³ | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|--|--|--|
| 20. Sensor and actuator calibration checks: on duct static pressure sensor on SAT, MAT, OSAT, OSA & RA damper and valve positions, SF cfm reading with TAB, and other random checks (EMS readout against hand-held calibrated instrument or observation must be within specified tolerances) | Manual | |
| 21. Verify schedules and setpoints to be reasonable and appropriate | | |

¹Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. Reduced Testing for Smaller Units. For standard application AHU’s less than 15 tons, the following modifications to the testing requirements apply: 1) either Manual or Monitoring will satisfy the verification requirement--where Both is listed, choose one. 2) Testing Modes 6, 8, 11, 13 and 16 is not required.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|---|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each AHU being tested: | | | | | |
| RAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| SAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| CC LAT (optional) | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| HC LAT (optional) | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| MAT | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| Indoor WB or enthalpy, if enthalpy economizer | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| SF speed, if variable, else status | 5 | 5 days incl. weekend | Y | Y | 1, 5-9 |
| RF speed, if variable, else status | 5 | 5 days incl. weekend | Y | Y | 1, 5-9 |
| Duct SP | 5 | 5 days incl. weekend | Y | Y | 1, 7, 9 |
| Building SP differential | 5 | 5 days incl. weekend | Y | Y | 8 |
| OSAT | 5 | 5 days incl. weekend | Y | Y | All |
| OSA-WB or enthalpy, if enthalpy economizer | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| Indoor dry-bulb ___ zones (expected to be most problematic) | 5 | 5 days incl. weekend | Y | Y | All |
| | | | | | |

Remarks:

CCV position (optional)
HCV position (optional)
SF cfm not required if not monitored
RF cfm not required if not monitored

- G. Acceptance Criteria (referenced by function or mode ID)
- 1-21. For the conditions, sequences and modes tested, the AHU, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
 2. AHU with supporting systems shall be able to maintain the SA temperature within 1.0F either side of the deadband of the current setpoint without excessive hunting.
 7. AHU and controls shall control the duct static pressure so that it does not drift more than an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.
- H. Sampling Strategy for Identical Units
1. All identical AHU's over 15 tons shall not have any sampling--test all units. However, 25% of the units may have monitoring be the verification method for modes listed with Monitoring or Both as testing methods, with no less than three units being fully tested per the above requirements.
 2. All identical AHU's equal to or less than 15 tons shall be sampled:
Randomly test at least 50% of each group of identical equipment (the 1st sample) per the above tests. In no case test less than three units in each group. If 20% of the units in the first sample fail the functional performance tests, test another the remaining 50%, fully at the contractor's expense. This sampling applies to the testing subsections. That is, if calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.
 3. All units not included in the sampling testing and monitoring shall be fully monitored for the monitoring modes listed above in the monitoring section.

END OF REQUIREMENTS FOR AHU TEST

2. BOILER SYSTEM (Heating Water)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls, as needed.
2. HVAC mechanical contractor or vendor: assist in testing sequences.
3. CA: to witness, direct and document testing.

B. Integral Components or Related Equipment Being Tested

1. Boiler
2. Primary HW supply pumps
3. Heating water piping system
4. Secondary HW supply pumps
5. VFD on secondary pumps

Prefunctional Checklist ID

- PC-____
PC-____
PC-____
PC-____

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|--|--|--|
| General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. <u>Primary Side.</u> Lead/lag staging of boilers, optimization, capacity modulation, and primary HW supply pumps. | Both | Heating |
| 3. <u>Secondary Side.</u> Secondary WH supply pump staging, bypass valve operation, if no VFD and HWT reset. VFD operation: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, verification of program settings,, alarms, etc. | Both | Heating |
| 4. Check all alarms and safeties (high and low pressure and temperature, etc.), PRV and flow switch functions | Manual | |
| 5. Test each possible lead boiler as lead boiler, and each pump as lead pump. Test pump lockouts. | Manual | |
| 6. Flue gas analysis verification, optional | Manual | |
| 7. Efficiency and capacity tests, optional | Manual | Heating |
| 8. Verify boiler inlet/outlet pressures with startup report and manufacturer's recommendations | Manual | |
| 9. Sensor and actuator calibration checks on: HWST, HWRT, pressure sensor controlling pump speed, mixing valve and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure setpoint, with a test gage) | Manual | |

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|---|--|--|
| 10. Constancy of differential pressure (pump control parameter) | Monitoring | Heating |
| 11. Verify schedules and setpoints to be reasonable and appropriate | | |

¹Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. False load boiler, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|--|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each boiler and pump: | | | | | |
| Boiler current or status | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| HWST | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| HWRT | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| OSAT-DB | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| HWS primary pump current or status | 5 | 5 days incl. weekend | Y | Y | 1, 2 |
| HWS secondary pump speed, if variable | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| HWS secondary pump flow rate, if in EMS | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| HWS secondary pump speed controlling parameter value | 5 | 5 days incl. weekend | Y | Y | 1, 3, 10 |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

- 1-11. For the conditions, sequences and modes tested, the boilers, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. Boiler shall maintain the supply water setpoint to within +/- 1.0F of setpoint deadband without excessive hunting.
- 9-10. Pumping system and controls shall maintain the current desired pressure setpoint to within an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.

H. Sampling Strategy for Identical Units

1. No sampling, test all.

END OF REQUIREMENTS FOR BOILER SYSTEM TEST

3. BUILDING AUTOMATION SYSTEM (BAS)

Spec writer:

If all BAS controlled systems or equipment are not going to be functionally tested and trended, additional monitoring, trending and point-to-point checkout will be required above what is outlined below. In fact, the BAS cannot really be functionally tested without functionally testing all the equipment it controls.

- A. Parties Responsible to Execute Functional Test
 1. Controls contractor: operate the controls to activate the equipment.
 2. CA: to witness, direct and document testing.

- B. Integral Components or Related Equipment Being Tested

| |
|-----------------------------------|
| <u>Prefunctional Checklist ID</u> |
| PC- _____ |
| --- |

 1. Building Automation System
 2. All prefunctional checklists of controlled equipment

- D. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

- E. A significant part of the BAS functional testing requirements is the successful completion of the functional tests of equipment the BAS controls or interlocks with. Uncompleted equipment functional tests or outstanding deficiencies in those tests lend the required BAS functional testing incomplete.

- F. Integral or stand-alone controls are functionally tested with the equipment they are attached to, including any interlocks with other equipment or systems and thus are not covered under the BAS testing requirements, except for any integrated functions or interlocks listed below.

- G. In addition to the controlled equipment testing, the following tests are required for the BAS, where features have been specified. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in the specifications.

| <u>Function / Mode</u> | <u>Test Method</u> Manual (demonstration), Monitoring, Either or Both |
|---|---|
| MISC. FUNCTIONS | |
| 1. All specified functions and features are set up, debugged and fully operable | Verbal discussion of features |
| 2. Power failure and battery backup and power-up restart functions | Demonstration |
| 3. Specified trending and graphing features demonstration | See equipment trends |
| 4. Global commands features | Demonstration |
| 5. Security and access codes | Demonstration |
| 6. Occupant over-rides (manual, telephone, key, keypad, etc.) | Demonstration |
| 7. O&M schedules and alarms | Demonstration |
| 8. Scheduling features fully functional and setup, including holidays | Observation in terminal screens or printouts |
| 9. Date and time setting in central computer and verify field panels read the same time | Demonstration |

SECTION 15997 – 10
MECHANICAL TESTING REQUIREMENTS

| Function / Mode | Test Method Manual (demonstration), Monitoring, Either or Both |
|---|--|
| 10. Included features not specified to be setup are installed (list) | Demonstration |
| 11. Occupancy sensors and controls | Demonstration |
| 12. Demonstrate functionality of field panels using local operator keypads and local ports (plug-ins) using portable computer/keypad | Demonstration of 100% of panels and 10% of ports |
| 13. All graphic screens and value readouts completed | Demonstration |
| 14. Setpoint changing features and functions | Done during equipment testing |
| 15. Communications to remote sites | Demonstration |
| 16. Sensor calibrations | Sampled during equipment tests |
| 17. "After hours" use tracking and billing | |
| 18. Final as-builts or redlines (per spec) control drawings, final points list, program code, setpoints, schedules, warranties, etc. per specs, submitted for O&Ms. | Observation |
| 19. Verify that points that are monitored only, having no control function, are checked for proper reporting to BAS. | Observation |
| INTEGRATED TESTS | |
| 20. Fire alarm interlocks and response | Demonstration |
| 21. Duty cycling (if specified) | Monitoring |
| 22. Demand limiting (including over-ride of limiting) | Monitoring |
| 23. Sequential staging ON of equipment | Either |
| 24. Optimum start-stop functions | Monitoring |
| 25. All control strategies and sequences not tested during controlled equipment testing | Either |
| 26. Other integrated tests specified in the contract documents | |
| 27. Security system interlocks | Demonstration |
| 28. Fire protection and suppression systems | Demonstration |

H. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

I. Additional Required Monitoring

1. Besides the trending and monitoring required with the functional testing of equipment, all points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|--|------------------|------------------------------|------------------|-------------------|-----------------------|
| Misc. equipment current or status for duty cycling and demand limiting | 5 | 5 days incl. weekend | Y | Y | 21-22 |
| Equipment or building kW or current for demand limiting | 5 | 5 days incl. weekend | Y | Y | 21-22 |
| Optimum start/stop equip. | 5 | 5 days incl. weekend | Y | Y | 24 |

Remarks:

I. Acceptance Criteria (referenced by function or mode ID)

All For the conditions, sequences and modes tested, the BAS, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

J. Sampling Strategy for Identical Units

1. Sample 10% of the field panels for procedure 9, and 10% of the local ports for procedure 12. If 10% fail, test another 10%. If 10% of those fail, test all remaining units at the contractor's expense.

END OF REQUIREMENTS FOR BAS TEST

4. CHILLER

The cooling tower can be tested integrally with the chiller testing. The cooling tower test requirements are listed elsewhere.

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls as needed.
2. HVAC mechanical contractor or vendor: assist in testing sequences as needed.
3. CA: to witness, direct and document testing.

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

C. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

- | | |
|--------------------------------|-----------|
| 1. Chiller | PC- _____ |
| 2. Primary CHW supply pumps | PC- _____ |
| 3. Chilled water piping system | PC- _____ |
| 4. Secondary CHW supply pumps | PC- _____ |
| 5. VFD on secondary pumps | PC- _____ |
| 6. Cooling tower | PC- _____ |

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are an addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test¹</u> |
|---|--|---|
| General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated. A full cycle from no load to full load and then to no load and compressors off shall be demonstrated. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. <u>Primary Side.</u> Lead/lag staging of chillers, optimization, capacity modulation (loading and unloading), heat reclaim, and primary CHW supply pumps, all relating to maintaining CDW and CHW temperatures. | Both | Cooling |
| 3. <u>Secondary Side.</u> Secondary CWH supply pump staging, bypass valve operation, if no VFD and CHWT reset. VFD operation: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, alarms, verification of program settings, etc. | Both | Cooling |
| 4. All alarms: high and low pressure, low oil, etc. | Manual | |
| 5. Test each possible lead chiller as lead chiller, and each pump as lead pump, including standby pumps. | Manual | |
| 6. kW/ton and APLV efficiency test, optional | Manual | Cooling |
| 7. Capacity test, optional | Manual | Cooling Design |

SECTION 15997 – 13
MECHANICAL TESTING REQUIREMENTS

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|---|--|--|
| 8. Sensor and actuator calibration checks on: ECDWT, CHWST, pressure sensor controlling pump speed, 3-way valve, and other random checks (EMS readout against handheld calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of the pressure setpoint, with a test gage) | Manual | |
| 9. Verify schedules and setpoints to be reasonable and appropriate | | |

¹Cooling season, Heating season or Both. “Design” means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

E. Special Procedures (other equipment with which to test, etc.; reference to function ID)

1. Test with cooling tower in automatic mode.
2. False load chiller, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|---|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each chiller and pump: | | | | | |
| Chiller current | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| ECDWT | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| LCDWT | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| CDW pump current or status | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| CHWST | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| CHWRT | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| OSAT-DB | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| CHWS primary pump current or status | 5 | 5 days incl. weekend | Y | Y | 1, 2 |
| CHWS secondary pump speed, if variable | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| CHWS secondary pump flow rate | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| CHWS secondary pump speed controlling parameter value | 5 | 5 days incl. weekend | Y | Y | 1, 3 |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

- 1-9. For the conditions, sequences and modes tested, the chillers, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. Chiller shall maintain the chilled water supply setpoint to within +/- 1.0F of setpoint deadband without excessive hunting.
9. Pumping system and controls shall maintain the current desired pressure setpoint to within an

amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.

- H. Sampling Strategy for Identical Units
 - 1. No sampling, test all.

END OF REQUIREMENTS FOR CHILLER TEST

5. COOLING TOWER

The cooling tower can be tested integrally with the chiller testing.

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls, as needed.
2. HVAC mechanical contractor or vendor: assist in testing sequences, as needed.
3. CA: to witness, direct and document testing.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

- | | |
|----------------------------------|----------|
| 1. Condenser water pump | PC-_____ |
| 2. Cooling tower and components | PC-_____ |
| 3. Condenser water piping system | PC-_____ |
| 4. Fan VFD | PC-_____ |

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are an addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|---|--|--|
| General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks with which it is associated. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Cooling season modes of operation. | Both | Cooling |
| 3. Heating season modes of operation. | Both | Heating |
| 4. Lead/lag staging of towers, including testing each tower as lead tower. Staging of fans, spray pumps, condenser pumps, CDWT reset, time delays. | Both, except ² | |
| 5. Bypass valve operation and ability of CT to maintain entering CDW temperature. | Either | |
| 6. Sump heater and freeze protection operation. | Either | Heating |
| 7. All alarms: vibration, fan failure, high water, low water. | Manual | |
| 8. Verify approach temperature with manuf. specs, optional. | Either | |
| 9. VFD operation: modulation to low limit, controlling PID, proportional band of speed vs control parameter, verification of program settings, alarms. | Both | |
| 10. Capacity test, optional. | Manual | Clg. Des. |
| 11. Sensor and actuator calibration checks: See Chiller requirements. | Manual | |
| 12. Verify schedules and setpoints to be reasonable and appropriate. | | |

¹Cooling season, Heating season or Both. “Design” means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that testing can be executed during any season, if condition simulation is appropriate.

²Monitoring testing each tower as lead tower is not necessary.

- E. Special Procedures or Conditions (other equipment to test with, etc.; reference to function ID)
1. Tests to be made with chiller in automatic mode.
 2. False load chiller, if necessary.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|-----------------------------------|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each CT: | | | | | |
| CDEWT | 5 | Wed. - Sat | Y | Y | 1, 2, 4, 9 |
| CDLWT | 5 | Wed. - Sat | Y | Y | 1, 2, 4, 8, 9 |
| OSAT-DB | 5 | Wed. - Sat | Y | Y | 1, 2, 4, 8,9 |
| OSAT-WB (optional) | 5 | Wed. - Sat | Y | Y | 8 |
| Fan motor speed, stage or current | 5 | Wed. - Sat | Y | Y | 4, 9 |
| CDW pump status or current | 5 | Wed. - Sat | Y | Y | 1, 2, 4, 9 |
| Each chiller status or current | 5 | Wed. - Sat | Y | Y | 1, 2, 4, 9 |
| | | | | | |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

- 1-12. For the conditions, sequences and modes tested, the cooling tower(s), integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
5. Cooling tower should be able to maintain the current specified setpoint for entering condenser water to within +/- 2F, when outside conditions do not restrict this thermodynamically.

H. Sampling Strategy for Identical Units

1. No sampling, test all.

END OF REQUIREMENTS FOR COOLING TOWER TEST

6. EXHAUST FANS

The testing requirements apply to the following fans (check all that apply): __central restroom, __mechanical room, __stairwell pressurization, __elevator pressurization, __kitchen hood, __garage

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment, if BAS controlled.
2. CA: to witness, direct and document testing.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Exhaust fans

PC-_____

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both ¹ | <u>Required</u> <u>Seasonal</u> <u>Test</u> |
|--|--|---|
| General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Verify schedules and setpoints to be reasonable and appropriate | | |
| 3. Function at fire alarm (off, depressurization, etc.) | Manual | |
| 4. Interlocks to building pressurization control | Manual | |
| 5. Speed controls | Either | |
| 6. Check TAB report record of sound power level tests and space pressures and compare to specifications | Review | |
| 7. Sensor calibration checks on any controlling temperature or pressure sensor | Manual | |

¹Refer to Special Procedures

E. Special Procedures (other equipment to test with, etc.; reference to function ID)

None

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|------------------|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each fan: | | | | | |
| Do be determined | | | | | |
| | | | | | |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

- 1-6. For the conditions, sequences and modes tested, the fans, integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

H. Sampling Strategy for Identical Units of the same type and function, but different in size, are considered identical for sampling purposes.

1. Randomly test at least 10% of each group of identical equipment (the 1st sample). In no case test less than three units in each group. If 10% of the units in the first sample fail the functional performance tests, test another 10% of the group (the 2nd sample). If 10% of the units in the 2nd sample fail, test all remaining units in the whole group, fully at the contractor's expense. This sampling applies to the testing subsections. That is, if calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.

END OF REQUIREMENTS FOR EXHAUST FAN TEST

7. INDOOR AIR CLIMATE CONTROL--MISC. SYSTEMS

At least 10% of all space zones shall be verified to be maintaining proper climate control. Specific test requirements for this may have been identified elsewhere in this specification (e.g., under terminal units). For all areas not specifically specified, otherwise, the following tests shall be conducted.

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls and provide trend logs
2. CA: to witness, direct and document testing.

B. Integral Components or Related Equipment Being Tested

1. Cooling plant (entire system)
2. Heating plant (entire system)
3. Air, water or steam distribution system
4. Control system

C. Prerequisites All listed systems in Part B, above, shall have had successful functional tests completed prior to this test.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

This is a performance test to verify that the HVAC systems can provide and maintain the temperature and relative humidity levels specified, during normal and extreme weather and occupancy conditions. The test consists of monitoring, via trend logs, of various points during the cooling season when temperatures reach to within 5°F of season design (ASHRAE 2 1/2%).

E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. Building should be normally occupied during the test.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|----------------------------|------------------|------------------------------|------------------|-------------------|-----------------------|
| Space temperature control: | | | | | |
| Space temperature | 5 | 5 days incl. weekend | Y | Y | 1-3 |
| OSAT-DB | 5 | 5 days incl. weekend | Y | Y | 1-3 |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

1. Space temperature during occupied modes shall average within +/- 1°F of setpoint and always remain within 1°F of the ends of the deadband without excessive hunting of either the applicable damper or coil valve, or complaints of drafts or stuffiness from occupants.

H. Sampling Strategy for Identical Units of the same type and function, but different in size, are considered identical for sampling purposes.

1. Randomly test at least 10% of each group of identical equipment (the 1st sample). In no case test less than three units in each group. If 10% of the units in the first sample fail the functional performance tests, test another 10% of the group (the 2nd sample). If 10% of the units in the 2nd sample fail, test all remaining units in the whole group, fully at the contractor's expense. This sampling applies to the testing subsections. That is, if

calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.

Spec Writer: For critical applications, or in demanding climates, add language to also verify that the specified relative humidity in the space is being maintained in a sampling of zones. The sample will likely be smaller than that for dry bulb verification, as the BAS will not likely monitor RH, and datalogging is costly.

END OF REQUIREMENTS FOR INDOOR AIR CLIMATE CONTROL TEST

8. INDOOR AIR QUALITY CHECK (IAQ)

IAQ checking activities are not technically “functional testing.” However, they are included here for consistency. Indoor air quality (IAQ) commissioning does not ensure that indoor air quality will be adequate or without deficiency at building turnover or during occupancy, unless the owner has specifically specified that actual air quality testing be performed. Commissioning for indoor air quality entails performing tasks that minimize the potential for IAQ problems, but it does not eliminate their possibility. The primary source for this checklist was Annex C in *ASHRAE Guideline 1-1989R The HVAC Commissioning Process*, Public Review Draft, 1996.

Spec Writer:

The IAQ checks here should be carefully reviewed for completeness and applicability to the current project and the Owner’s documented program regarding IAQ. In particular, specifying any actual “testing” can have significant cost and liability ramifications.

- A. Parties Responsible to Perform IAQ Checks
 - 1. CA: performs and oversees checks, inspections and reviews.
 - 2. TAB contractor: performs checks using test instruments for tasks under Part C
- C. Prerequisites CA will perform each check and review as soon as the materials or work is such that IAQ related determinations can be made.
- D. Purpose. The purpose of the IAQ check is to minimize the potential for IAQ problems in the facility during occupancy. The CA is not responsible for any IAQ issues during construction, nor for IAQ issues in the occupied part of the facility, if construction is being performed in other parts of the facility.
- E. The following tasks will be conducted and documented:

Spec Writer: Edit and enhance this list as appropriate. Performing all tasks on this list is currently rarely done by commissioning agents.

More specificity will also be needed on many of the tasks before the TAB and CA can bid this work.

- 1. Submittal Reviews

Compare specified data with submitted data sheets for the following:

 - a. Filtration and filter type.
 - b. Materials that had specifications for emissions rates as part of the contract documents.
 - c. HVAC materials that have a potential for airflow erosion, corrosion and microbial contamination (HVAC insulation materials, etc.).
 - d. Manufacturer’s safety data sheets (MSDS) for products specified in the contract documents that may be suspected contributors to indoor pollutants (carpets, flooring, fabrics, adhesives, wall coverings, partitions, and ceilings; insulating and fire-proofing materials; sealants on walls and floors; use of preservatives, paints, varnishes, and other finish materials).
- 2. Static Inspections and Checks

- a. Review the code compliance calculations for accuracy.
 - b. Verify that the outdoor air intakes are sized and located according the plans and specifications.
 - c. Verify that no outside conditions exist that could compromise the quality of the air entering the outdoor intakes.
 - d. Inspect air intakes and exhausts for short-circuiting.
 - e. Document any required ductwork cleaning.
 - f. Prior to building turnover, verify that final filters are installed and coils, inside of units and ductwork is clean.
 - g. Inspect air supply system components to ensure control and minimization of the presence of free and standing water and to minimize microbial contamination (condensate trays, traps, humidifiers, water baffles, mist eliminators and cooling towers).
 - h. Verify proper access for cleaning of both sides of coils, condensate pans and/or humidifier reservoirs in all HVAC equipment.
 - i. Meet with contractors and review any specified manufacturer’s recommended curing, drying and airing procedures (for minimizing emission rates). Document the compliance of the contractors.
 - j. When the building is partially occupied during construction, meet with the Contractor and issue a plan in writing for operation of the HVAC system. The plan will describe how the system can be operated at as close to normal operating conditions as possible, to minimize dust and dirt from contaminating the ductwork and coils and polluting the occupied areas, and to prevent damaging moisture migration.
 - k. Review TAB reports for consistency with the specifications.
 - l. After completion of TAB, review with the TAB contractor, any areas they may consider as being potentially problematic regarding maintaining adequate minimum outdoor air, proper exhaust or room pressure differential.
3. Air Flow and Pressurization Checks
- a. Verify that the specified minimum ventilation rates are maintained during all occupied modes of operation, particularly during VAV terminal box turn-down.
 - b. Spot-check TAB supply air flow readings in critical areas.
 - c. Spot-check the TAB measurements and setup of the exhaust systems for each area. When purging is specified in the contract documents, develop a plan for, and see that the Contractor purges the building prior to occupancy.
 - d. Verify that the total building pressurization criteria is met through varying HVAC loads and economizing conditions.
 - e. Verify that room pressure differentials are as specified between critical areas (clean rooms, bio-hazards, film developing rooms, chemical storage areas, etc.).
 - f. Verify that the design engineer’s specification for interstitial and area pressurization differentials has been met.

Spec Writer: The following procedures require considerably more detail than is given here to specify a requirement. The verification concepts are mentioned for reference only.

4. Verification

- a. Verify that the specified ventilation effectiveness throughout the various areas of the building is

being met by: ___ smoke tube testing for airflow patterns, ___ flow hood readings, ___ air contaminant monitoring,
___ other _____.

- b. Perform IAQ testing using the following methods (surface cultures for microbial contamination, airborne culture testing, CO₂ monitoring, VOC monitoring, CO monitoring, etc.).

I. Acceptance Criteria

Unless noted in the requirements, the commissioning agent in concert with the CM will make determinations and interpretations for when IAQ issues are considered to be in compliance with the contract documents.

END OF IAQ REQUIREMENTS

9. PACKAGED DX AIR CONDITIONING OR HEAT PUMP UNITS

- A. Parties Responsible to Execute Functional Test
 1. Controls contractor: operate the controls to activate the equipment.
 2. CA: to witness, direct and document testing.
- B. Integral Components or Related Equipment Being Tested Prefunctional Checklist ID
 1. Unit (fans, coils, condenser, compressors, ducts, VFD) PC-_____
 2. Heat recovery coil, humidifier or direct / indirect evaporative cooling sections PC-_____
- C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.
- D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements
 The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both ³ | <u>Required Seasonal Test</u> ¹ |
|---|--|--|
| General | | |
| 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Mixed and supply air, and reset temp. control functions | Both | |
| 3. Economizer functions | Both | Cooling |
| 4. SF, RF and exhaust fan interlocks | Either | |
| 5. Compressor unloading & condenser fan staging for head pressure control | Both | |
| 6. Demand limiting control (if applicable) | Monitoring | Cooling |
| 7. Duct static pressure (SP) control | Both | |
| 8. Return or exhaust fan tracking and building SP | Monitoring | |
| 9. VFD (or inlet vanes) operation on SF and RF: modulation to minimum, control system PID, proportional band of speed vs controlling parameter, constancy of static pressure, verification of program settings, alarms, etc | Both | ² |
| 10. Damper interlocks and correct modulation in all modes, including fire and smoke dampers | Manual | |
| 11. Temperature difference across heating and cooling coils, if spec'd | Manual | |
| 12. Verification of minimum OSA quantity and control through varying VAV box positions | Either | ² |
| 13. Branch duct control damper control | Manual | |
| 14. Night low and high limit, morning warmup cycle, | Either | |
| 15. Heat recovery operation | Monitoring | |
| 16. Verify TAB reported SF cfm with control system reading | Manual | ² |
| 17. All alarms (low limits, high static, freezestat, etc.) | Manual | |
| 18. Unit heating and cooling capacity tests, optional | Manual | Design |

SECTION 15997 – 25
MECHANICAL TESTING REQUIREMENTS

| Function / Mode | Test Method Manual, Monitoring, Either or Both ³ | Required Seasonal Test ¹ |
|--|---|---|
| 19. Heating and cooling EER or COP efficiency tests, optional | | Design |
| 20. Change over function from heating to cooling and defrost (heatpumps) | Manual | |
| 21. Sensor and actuator calibration checks on: duct static pressure sensor on units >10 tons, SAT, MAT, OSAT, economizer and RA dampers and other random checks (EMS readout against hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure setpoint, with an inclined manometer) | Manual | |
| 22. Verify control strategies, schedules and setpoints to be reasonable and appropriate | | |

¹Cooling season, Heating season or Both. “Design” means within 5° of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

E. Special Procedures (other equipment to test with, etc.; reference to function ID)

1. Reduced Testing for Smaller Units. For standard application AHU’s less than 15 tons, the following modifications to the testing requirements apply: 1) either Manual or Monitoring will satisfy the verification requirement--where Both is listed, choose one. 2) Testing Modes 6, 8, 11, 13 and 16 is not required.

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|-----------------------------|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each Unit being tested: | | | | | |
| RAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5, 19 |
| SAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| CC LAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| HC LAT | 5 | 5 days incl. weekend | Y | Y | 1-3, 5 |
| MAT | 5 | 5 days incl. weekend | Y | Y | 1, 3, 19 |
| Indoor WB or enthalpy | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| SF speed | 5 | 5 days incl. weekend | Y | Y | 1, 5-9 |
| RF speed | 5 | 5 days incl. weekend | Y | Y | 1, 5-9 |
| Duct SP | 5 | 5 days incl. weekend | Y | Y | 1, 7, 9 |
| Building SP differential | 5 | 5 days incl. weekend | Y | Y | 8 |
| OSAT | 5 | 5 days incl. weekend | Y | Y | All |
| OSAT-WB or enthalpy | 5 | 5 days incl. weekend | Y | Y | 1, 3 |
| Indoor dry-bulb zones | 5 | 5 days incl. weekend | Y | Y | All |
| Compressor amps or stage | 5 | 5 days incl. weekend | Y | Y | 5 |
| Condenser fan amps or stage | 5 | 5 days incl. weekend | Y | Y | 5 |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

- 1-22. For the conditions, sequences and modes tested, the system, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.
2. RTU shall be able to maintain the SA temperature within 1.0F either side of the deadband of the current setpoint without excessive hunting.
7. RTU and controls shall control the duct static pressure so that it does not drift more than an amount equal to 10% of the setpoint value either side of the deadband without excessive hunting.

H. Sampling Strategy for Identical Units

1. All identical AHU's over 15 tons shall not have any sampling--test all units. However, 25% of the units may have monitoring be the verification method for modes listed with Monitoring or Both as testing methods, with no less than three units being fully tested per the above requirements.
2. All identical AHU's equal to or less than 15 tons shall be sampled:
Randomly test at least 50% of each group of identical equipment (the 1st sample) per the above tests. In no case test less than three units in each group. If 20% of the units in the first sample fail the functional performance tests, test another the remaining 50%, fully at the contractor's expense. This sampling applies to the testing subsections. That is, if calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.
3. All units not included in the sampling testing and monitoring shall be fully monitored for the monitoring modes listed above in the monitoring section.

END OF REQUIREMENTS FOR PACKAGED UNIT TEST

10. SERVICE HOT WATER SYSTEM

A. Parties Responsible to Execute Functional Test

1. CA: perform and document testing.

B. Integral Components or Related Equipment Being Tested

1. Hot water heaters (heaters, mixing valves)
2. Recirculating pumps

Prefunctional Checklist ID

- PC- _____
PC- _____

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both | <u>Required</u> <u>Seasonal</u> <u>Test</u> |
|--|--|---|
| General 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, shutdown, unoccupied & manual modes and power failure. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Verify schedules and setpoints to be reasonable and appropriate | | |
| 3. Unoccupied pump operation | Either | |
| 4. Mixing valve operation and temperature control | Either | |
| 5. Sensor calibration checks on hot water temperature | Manual | |
| | | |

E. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

F. Required Monitoring
None

G. Acceptance Criteria (referenced by function or mode ID)
1-6. For the conditions, sequences and modes tested, the fan’s integral components and related equipment respond to changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

H. Sampling Strategy for Identical Units
1. No sampling. Test all units.

END OF REQUIREMENTS FOR SERVICE HOT WATER SYSTEM TEST

11. TERMINAL UNITS

(This applies to standard applications, critical applications will have additional tests and a higher fraction tested.)

A. Parties Responsible to Execute Functional Test

1. Controls contractor: operate the controls to activate the equipment.

B. Integral Components or Related Equipment Being Tested

Prefunctional Checklist ID

1. Terminal unit (TU)

PC-_____

C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

D. Functions / Modes Required To Be Tested, Test Methods and Seasonal Test Requirements

The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Function / Mode</u> | <u>Test Method</u> Manual, Monitoring, Either or Both ³ | <u>Required</u> <u>Seasonal</u> <u>Test</u> ¹ |
|--|--|--|
| General | | |
| 1. Test each sequence in the sequence of operations, and other significant modes and sequences not mentioned; including startup, warmup, shutdown, unoccupied & manual modes and power failure and restoration. Test functionality of this piece of equipment or system in all control strategies or interlocks that it is associated with, including all damper, valve and fan functions. | Manual | |
| In addition to, or as part of (1) above, the following modes or tests are required: | | |
| 2. Sensor activator calibration checks on: SAT, MAT, zone air temperature damper position and other random checks (EMS readout against visual or hand-held calibrated instrument must be within 0.5°F for temps. or within a tolerance equal to 10% of static pressure setpoint, with an inclined manometer) | Manual | |
| 3. Device and actuator calibration and stroke checks for heating coil valve and non-DDC dampers | Manual | |
| 4. For the TU's tested, check the prefunctional checklist items. | Observation | |
| 5. Verify control parameters and setpoints to be reasonable and appropriate by reviewing the full program of 5% of all the TU's with each other for consistency. Verify the max. and min. cfm setpoints of all tested TU's against the control drawing and TAB values. Verify other TU programming parameters such as K-factors, deadbands, setpoints, stroke times, etc. | Observation | |
| 6. Verify no CCV flow when there is HCV flow | Either | |
| 7. Verify no hunting or significant overshoot by damper or valves. | Either | |
| 8. Verify by measurement, CCV & HCV positive shutoff (no leak-thru) | Manual | |
| 9. Verification of minimum OSA control through varying VAV box positions, if applicable | Either | ² |
| 10. All alarms (fan status, low limits, high static, etc.) | Manual | |
| 11. Verify that TU is maintaining space setpoint temperatures | Monitoring | Both Design |
| 12. Verify airflows and pressures (this random test is part of the TAB test) | -- | |

NOTES:

¹Cooling season, Heating season or Both. “Design” means within 5°F of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

²Seasonal test not required if seasonal conditions can be adequately simulated.

³Refer to Special Procedures

E. Special Procedures (other equipment to test with, etc.; reference to function ID)
None

F. Required Monitoring

1. All points listed below which are control system monitored points shall be trended by the controls contractor. Other points shall be monitored by the CA using dataloggers. Refer to the Monitoring section at the beginning of Section 15997 for additional monitoring details.

| Point | Time Step (min.) | Minimum Time Period of Trend | Hard Copy? (Y/N) | ASCII File? (Y/N) | Function Being Tested |
|--|------------------|------------------------------|------------------|-------------------|-----------------------|
| For each zone thermostat and space sensor and other critical areas, monitor: | | | | | |
| Space temperature | 10 | 3 weekdays, summer design | Y | Y | 11 |
| Space temperature | 10 | 3 weekdays, winter design | Y | Y | 11 |
| Space temperature | 2 | 8 hours, occupied | Y | Y | 7 |
| Heating coil valve | 2 | 8 hours, occupied | Y | Y | 7 |
| Damper position or cfm | 2 | 8 hours, occupied | Y | Y | 7 |

Remarks:

G. Acceptance Criteria (referenced by function or mode ID)

1-11. For the conditions, sequences and modes tested, the TU, integral components and related equipment respond to varying loads and changing conditions and parameters appropriately as expected, as specified and according to acceptable operating practice.

10. Space temperature during occupied modes shall average within +/- 1°F of setpoint and always remain within 1°F of the ends of the deadband without excessive hunting of either the damper or coil valve, or complaints of drafts or stuffiness from occupants.

H. Sampling Strategy for Identical Units of the same type and function, but different in size, are considered identical for sampling purposes.

1. Testing. Randomly test at least 10% of each group of identical equipment (the 1st sample). In no case test less than three units in each group. If 10% of the units in the first sample fail the functional performance tests, test another 10% of the group (the 2nd sample). If 10% of the units in the 2nd sample fail, test all remaining units in the whole group, fully at the contractor’s expense. This sampling applies to the testing subsections. That is, if calibration is off on more than 10% of the tested piece of equipment, then another sample shall have calibrations checked, but not all other tests need to be done on the second sample.

2. Monitoring. Ten percent of the total number of zones in the building, chosen by the Owner, shall be monitored. Within this 10%, shall be included a distribution of all air handlers, zones expected to have the greatest heating and cooling demand, perimeter and core zones and zones identified from the commissioning process that have exhibited potential problems.

Spec Writer: For critical applications, or in demanding climates, add language to also verify that the specified relative humidity in the space is being maintained in a sampling of zones.

The sample will likely be smaller than that for dry bulb verification, as the BAS will not likely monitor RH, and datalogging is costly.

Also, for critical applications, significantly more than say 10%, may need to be positively and independently verified.

END OF REQUIREMENTS FOR TERMINAL UNIT TEST

12. TEST AND BALANCE WORK (TAB)

- A. Parties Responsible to Execute Functional Test
 - 1. TAB contractor: perform checks using test instruments.
 - 2. Controls contractor: operate the controls to activate the equipment.
 - 3. CA: to witness, direct and document testing.

- B. Integral Components or Related Equipment Being Tested Prefunctional Checklist ID
 - 1. TAB water-side PC-_____
 - 2. TAB air-side PC-_____

- C. Prerequisites The applicable prerequisite checklist items listed in the beginning of Section 15997 shall be listed on each functional test form and checked off prior to functional testing. The commissioning agent will also spot-check misc. items and calibrations on the prefunctional checklists previously completed by the installer, before the beginning of functional testing.

- D. Purpose. The purpose of this test is to spot check the TAB work to verify that it was done in accordance with the contract documents and acceptable practice and that the TAB report is accurate.

- E. The following tests and checks will be conducted. The following testing requirements are in addition to and do not replace any testing requirements elsewhere in this Division.

| <u>Test or Check</u> | <u>Test Method</u> | <u>Required Seasonal Test³</u> |
|--|--------------------|---|
| <p>1. A random sample of up to _____ % the TAB report data shall be selected for verification (air velocity, air or water flow rate, pressure differential, electrical or sound measurement, etc.). The original TAB contractor will execute the checks, witnessed by the commissioning authority. The TAB contractor will use the same test instruments as used in the original TAB work.</p> <p>A failure¹ of more than 10% of the selected items of a given system² shall result in the failure of acceptance of the system TAB report and the TAB contractor shall be responsible to rebalance the system, provide a new system TAB report and repeat random verifications of the new TAB report.</p> <p>The random testing will include the verification of minimum outdoor air intake flows at minimum, maximum and intermediate total airflow rates for _____ % of the air handlers. Other selected data to be verified will be made known upon day of testing.</p> | Demonstration | |
| <p>2. Verify that final settings of all valves, splitters, dampers and other adjustment devices have been permanently marked by the TAB Contractor.</p> | Demonstration | |
| <p>3. Verification that the air system is being controlled to the lowest possible static pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from fan to diffuser having all balancing dampers wide open and that during full cooling of all TUs taking off downstream of the static pressure sensor, the TU on the critical leg has its damper 90% or more open.</p> | Demonstration | |

| <u>Test or Check</u> | <u>Test Method</u> | <u>Required Seasonal Test</u> ³ |
|---|--------------------|--|
| 4. Verification that the water system is being controlled to the lowest possible pressure while still meeting design loads, less diversity. This shall include a review of TAB methods, control setpoints established by TAB and a physical verification of at least one leg from the pump to the coil having all balancing valves wide open and that during full cooling the cooling coil valve of that leg is 90% or more open. | Demonstration | |

¹Failure of an item is defined as follows:

- For air flow of supply and return: a deviation of more than 10% of instrument reading
- For minimum outside air flow: 20% of instrument reading (30% for reading at intermediate supply flow for inlet vane or VFD OSA compensation system using linear proportional control)
- For temperatures: a deviation of more than 1°F
- For air and water pressures: a deviation of more than 10% of full scale of test instrument reading
- For sound pressures: a deviation of more than 3 decibels. (Variations in background noise must be considered)

²Examples of a “system” are: the air distribution system served by one air handler or the hydronic chilled water supply system served by a chiller or the condenser water system. Systems can be defined smaller if inaccuracies in TAB work within the smaller defined system will have little or no impact on connected systems.

³Cooling season, Heating season or Both. “Design” means within 5% of season design (ASHRAE 2 1/2%), or 95% of loading design. A blank cell denotes no special seasonal test is required and that test can be executed during any season, if condition simulation is appropriate.

- F. Special Procedures (other equipment to test with, etc.; reference to function ID)
None
- G. Required Monitoring
None
- I. Acceptance Criteria (referenced by function or mode ID)
Provided in footnote to test table above.
- J. Sampling Strategy for Identical Units
Described in test table above.

END OF REQUIREMENTS FOR TAB TEST

END OF THIS GUIDE SPECIFICATION SECTION