

SECTION 01915 - FUNCTIONAL PERFORMANCE TESTING (FPT) PROCEDURES - CONSTRUCTION MANAGER EDITION

PART 1 – GENERAL

1.1 Section includes:

- A. Functional Performance Testing of Systems: Functional Performance Testing (FPT) process, procedures, and requirements. It is intended to illustrate (i) Contractor's requirements for assisting Commissioning Authority (CA) with Functional Performance Testing of systems, and (ii) to demonstrate level at which systems and equipment will be tested prior to being deemed 'Acceptable' to Owner.
- B. CA will prepare itemized and detailed testing plans and procedures that:
 - 1. Specify individual tests and procedures that meet general requirements of Cx plan and commissioning process;
 - 2. Serve to document and record testing procedures and results of tests.
- C. Contractor shall provide technical input to CA as needed during development of final project FPTs.
- D. Acceptance criteria
- E. Example (referred to herein as 'generic') FPTs are provided as illustration to Contractor of level of detail to which FPTs will be conducted.

1.2 Related Documents:

- A. Commissioning Plan: Cx Plan is part of Contract Documents and outlines many responsibilities, procedures and tasks throughout Cx process. It encompasses entire Cx process including phases prior to construction and roles of parties. It also describes Functional Performance Tests that will be performed during Acceptance Phase.
- B. Section 01910: Specifies general facility commissioning procedures common across all Divisions and the Contractor's responsibilities for the commissioning process.
- C. Section 15959 – Building Automation Systems Commissioning: Details commissioning procedures specific to Building Automation System.
- D. Section 15995 – Commissioning: Details commissioning procedures specific to Division 15 work.
- E. Individual Specification Sections: Individual sections stipulate installation, start-up, warranty, O&M documentation, and training requirements for system or device specified in Section.

1.3 Definitions and Abbreviations

- A. Refer to Section 01910.

1.4 Functional Performance Testing:

- A. Objectives and Scope:

1. Objective of functional performance testing is to demonstrate that each system is operating according to documented design intent and Contract Documents. Functional testing facilitates bringing systems from a state of substantial completion to full dynamic operation. Additionally, during testing process, areas of deficient performance are identified by CA and corrected by responsible Contractor, improving operation and functioning of systems.
 2. Each system shall be operated through modes of operation (seasonal, occupied, unoccupied, warm-up, cool-down, part- and full-load) where there is a specified system response. Verifying each sequence in sequences of operation is required. Proper responses to such modes and conditions as power failure, freeze condition, low oil pressure, no flow, equipment failure, etc. shall also be tested.
- B. Development of Test Procedures: CA shall develop specific test procedures and forms to verify and document proper operation of each piece of equipment and system. Prior to execution, CA shall provide a copy of initial test procedures to Contractor who shall review tests for feasibility, safety, equipment and warranty protection, and scope. CA will also submit tests to A/E for review.
1. Contractor shall review FPTs in detail.
 2. CA shall review Owner-contracted testing, factory testing, or required Owner acceptance tests for which CA is not responsible to oversee. Review shall include content, scope, and documentation format, and shall determine what further testing or format changes may be required. Redundancy of testing shall be minimized.
 3. Purpose of any given specific FPT is to verify and document compliance with stated criteria of acceptance.
- C. Scheduling: After Contractors notification that systems are ready for initial testing and submittal and review of required submittals has occurred, Owner shall schedule testing. To extent practical, tests shall be scheduled to allow efficient and contiguous testing of inter-related systems and equipment.
1. Phasing: Non-interdependent segments of project testing can be phased. Phasing shall be determined based on schedule for Owner Occupancy by area. Schedule and planning shall allow adequate time for functional performance testing prior to building occupancy.
- D. Participation: CA will direct Functional Performance Tests after Start-Up Procedure documentation of systems and equipment has been reviewed and accepted. Conceptual procedures for functional performance testing are outlined elsewhere in this Section. CA will execute FPTs unless otherwise specified. Contractor shall assist as described above with manipulation of systems or equipment, provision of supporting equipment or materials (lifts, ladders, specialty test equipment, safety equipment), and immediate remediation of minor identified deficiencies whenever possible. Required participation is outlined in generic FPTs provided elsewhere in this Section.
1. Required participating parties shall be indicated with individual FPT. Typically, multiple parties are required for any given test, yet participation for any given party is only required for respective portion of test for which party is responsible. For instance, controls contractor does not have to be present for capacity testing of an air handler, only control-related portion of test. In many cases, maximum required time in hours is indicated in parenthesis for given test. Time is typically **per unit** system unless indicated otherwise (i.e.: 1 hr per air handler tested). If no time is indicated, participation is required throughout entire test.
 2. Frequently, on multiple samples where a given party does not directly conduct test, participation of that party will only be required for an initial quantity of systems/equipment. Whenever practical and at discretion of CA, CA will continue

with remaining portion of sample without assistance from Contractor. In this case, time requirement will be indicated as a total. However, Contractor is allowed to be present at their option for any or all FPTs conducted.

3. It is required that parties be available on-site throughout testing of given system for which they are required participants. Therefore, time for which they are not directly involved can be spent performing or work (typically addressing identified punch list items or failed tests).
 4. No party involved with project is prohibited from participation in or witnessing of tests. Contractor may elect to witness tests on systems even if involvement is not directly required (for instance, controls contractor involvement is sometimes required on first few of a sample and not on entire sample).
 5. CA will endeavor to coordinate effectively with individual Contractors throughout FPT and minimize required involvement.
- E. Detailed Test Procedures and Contractor Review: CA will prepare detailed and itemized testing procedures to define and document FPT. These will be developed during Construction Phase and completed during Acceptance Phase. CA shall submit these procedures to Contractor for review. Contractor shall indicate required limitations, safety procedures, maximum thresholds, and other parameters during FPT development. (Contractor shall be responsible for any damage to equipment caused by functional performance testing done per procedures and within limitations of approved procedures.)
- F. Completeness: Systems must be completed and ready for FPT. Start up, factory authorized field testing, independent testing agency tests, and TAB procedures must be complete and control systems must be tested and started for respective system or component.
- G. Test Documentation: CA will conduct tests, and/or witness tests as applicable. CA will record test results on forms developed for testing. CA will 'Pass' or 'Fail' testing and record date and time of test. Deficiencies shall clearly be indicated when test is failed. When related testing is completed successfully, CA shall recommend acceptance of system or component.
- H. Deficiencies and Re-Testing: When deficiencies are identified during testing, depending on extent or magnitude, they can be corrected during test and testing can continue to successful completion. More significant deficiencies will require failure of test and re-testing. Deficiencies of this magnitude will result in an Action Item on Action List and resolution is responsibility of the Contractor. (Resolution of deficiency will not subsequently be tracked by CA via Action List.) Tests shall be repeated until successful completion. Refer to more specific provisions below.
- I. Sampling: Some types of identical equipment (such as terminal devices) will be tested using a sampling strategy. Sample percentage is indicated in generic FPT provided elsewhere in this Section.
- J. Max Failure Limit and Sample Percentages:
1. A Maximum Failure Limit is indicated along with Sampling Percentages. Max Failure Limit indicates maximum percentage of tested devices that may have test that fails before an entirely new sample must be tested. This is based on concept that if many failures occur, it is a result of inadequate start-up by Contractor. When maximum number of failures is reached, testing on that sample will be terminated and re-testing will be scheduled.
 2. If no Max Failure Limit is indicated, tested samples must pass (Max Failure Limit 0%).
 3. Where sample tests involve multiple systems (i.e., checking strainers on different hydronic systems) Maximum Failure Limit will apply per system.

4. Responsible Contractors shall pay CA cost of that sample test, and redo start-up/TAB for applicable devices/systems.
 5. Work necessitated by sample failures shall be at no cost to Owner.
- K. Opposite Season Testing: Testing procedures shall be repeated as necessary during appropriate seasons. Opposite Season testing will be required where scheduling prohibits thorough testing of all modes of operation. Air handler and central heating system testing for heating-related modes of operation and control loops shall be tested during outside air temperatures below 35 degrees F.
- L. Approval. CA passes each test and subsequently recommends approval to Owner who reviews and approves FPT.

1.5 Coordination Between Testing Parties:

- A. Factory Start-Ups: For many systems and equipment, Factory Start-Ups are specified. Factory Start-Ups will be reviewed and checked during functional performance testing. Costs associated with Factory Start-Ups are included with bid unless otherwise noted. In general, Contractor shall make notification of when Factory Start-Ups are occurring and coordinate these with witnessing parties. CA and CxT members may witness Factory Start-Ups at their discretion. Aspects of functional performance testing accomplished during Factory Start-Ups may be accomplished and approved by CA if they meet intent of FPT.
- B. Independent Testing Agencies: For systems where Independent Testing Agencies are specified, cost of this testing is included with bid unless otherwise noted. Much of testing performed by these independent agencies will cover aspects required in Start-Up Procedures and functional performance tests.
1. Contractor and testing agencies shall coordinate with CA so that CA can witness testing and approve applicable aspects of FPTs.
 2. CA may in some cases independently spot-check work of testing agencies if tests were not witnessed. However, it is not the intent for CA to re-accomplish testing by others that is specified in construction specifications. For instance, much of testing requirements for electrical systems will be performed by independent electrical testing agency provided under bid. CA shall witness indicated sample of testing and record results in record of functional performance tests.
 3. Contractor is responsible for coordinating efforts of testing agency with that of Cx process. Documentation shall be contiguous and seamless and duplication should be avoided. Testing agencies shall complete documentation of Cx process as required.

1.6 FPT Acceptance Criteria:

- A. Acceptance Criteria shall be as follows unless more specifically indicated within individual tests. CA may exercise professional judgment to relax requirements and pass tests and recommend approval when appropriate.
1. Capacity and/or equipment performance will generally be as specified ± 5 percent.
 2. Efficiency where specifically indicated in documents will be ± 5 percent. When inferred from manufacturer's catalogue data, criteria will be ± 10 percent.
 3. Balancing-related criteria will be ± 5 percent for water and ± 10 percent for air.
 4. Accuracy/repeatability on sensing devices will be as specified for device. CA and TAB will use calibrated gages for independent validation and use judgment in

passing or failing devices. In many cases, coordination of multiple related sensors is more important than absolute accuracy.

5. Loop response and setpoint deviation criteria will be as specified in Section 15995.
6. HVAC sequence-related criteria will be as explicitly specified in documents and as interpreted by CA. Code required sequencing shall be per applicable code.
7. System sequences shall be as required by approved shop drawings.
8. Air Pressurization: As indicated in contract documents. If not indicated in documents, then it shall be as indicated in most current version of ASHRAE Handbooks for applicable occupancy. Smoke/shaft pressurization shall be as required by NFPA to maintain maximum door opening forces and to restrict passage of smoke.

PART 2 - PRODUCTS

2.1 Instrumentation:

- A. General: Testing equipment shall be of sufficient quality and accuracy to test and/or measure system performance with tolerances specified. Equipment shall be calibrated according to manufacturer's recommended intervals. Calibration tags shall be affixed or certificates readily available.
- B. Standard Testing Instrumentation: Standard instrumentation normally used for performance assessment and diagnosis will be provided by CA. These include:
 1. Electronic Manometer (for Air and Flow Hood)
 2. Electronic Manometer (for Water)
 3. Temperature Instruments and Gages
 4. Humidity Instrument and Gage
 5. CO² Instrument
 6. Electronic Multimeter
 7. Receptacle Tester
 8. Tachometer
 9. Belt Tensioner
 10. Ultrasonic Flow Meter
- C. Special Tools: Special equipment, tools and instruments (only available from vendor, specific to a piece of equipment) required for testing equipment, according to these Contract Documents shall be included in base bid price to Contractor and provided to Owner.

PART 3 – EXECUTION

3.1 Prerequisites:

- A. Equipment, components, and devices applicable to FPT must be started and Start-Up must be documented and passed. This includes completion of Start-Up Procedures, pressure testing of equipment, duct, piping; flushing/cleaning of applicable systems; completed labeling and identification; completed insulation of applicable systems; and/or requirements for placing system into dynamic operation.

- B. Unless specifically agreed to by Owner and CA, support systems shall be complete prior to FPT. For instance, an air handler will require that:
 - 1. Electrical system serving it is completed and tested;
 - 2. Hydroid systems serving it have been pressure tested, flushed, and functional performance tested;
 - 3. Balancing has been accomplished on air and water sides;
 - 4. Control systems have been started and calibrated.
- C. CA shall determine optimal sequence of testing.

3.2 Required Parties for Testing:

- A. Required participating parties shall be as indicated with individual FPT. Typically, multiple parties are required for any given test, yet participation for any given party is only required for respective portion of test for which party is responsible. For instance, BAC does not have to be present for capacity testing of an air handler, only control-related portion of test.
- B. In many cases, maximum required time in hours is indicated in parenthesis for any given test. Time is typically **per unit** system unless indicated otherwise (i.e.: 1 hr per air handler tested). If no time is indicated, participation is required throughout entire test.

3.3 Common Elements for Systems:

- A. Required submittal documentation shall be present and located convenient to testing area. Validate that required documentation has been submitted and is per contract requirements.
- B. Contractor shall provide completed Start-Up Procedures at time of testing. CA shall review Start-Up Procedure documentation and spot-check at beginning of FPT.
- C. Contractor shall demonstrate that access is sufficient to perform required maintenance.
- D. BAS trends shall have been established as required in documents. These shall generally be reviewed prior to or during FPT.
- E. Dynamic systems powered by electricity shall be tested to simulate a power outage to ensure proper sequencing. Those on emergency power or uninterruptible power shall be tested on all sources.
- F. Capacities and adjusted/balanced conditions as applicable shall be subject to check.
- G. Sequencing Verification: Modes of operation and actions shall be verified for equipment/system samples.
- H. System and equipment configurations shall be compared against contract documents.
- I. Verify Modes (such as heating and cooling) are coordinated and do not overlap or 'fight'.
- J. Adjusted, balanced, controlled systems shall be assessed to determine optimal setting for system as applicable. Optimal settings should be determined to establish reliable, efficient, safe and stable operation.
- K. BAS or Local Panel Dynamic Graphics: Graphic displays for components, systems, and areas required to be represented by a graphic shall be checked for adequacy and accuracy. Furthermore, when setpoints or parameters are required to be adjustable, CA shall verify that they can be adjusted directly from graphic screen.

- L. Emergency power tests for mechanical systems will be conducted in concert with testing of emergency power systems. Mechanical contractor shall be available for power outage test to test mechanical systems under a power outage. This is in addition to requirements specified for mechanical system.

3.4 TAB Verification of Mechanical Systems:

- A. CA shall review TAB reports.
- B. CA will select up to 10 percent of readings from balancing reports and require balancing contractor to spot-check. Maximum failure rate for this sample is 10 percent and system shall be re-balanced and re-documented if this rate is exceeded. Readings selected by CA may include supply air diffuser readings (both minimum and maximum readings for VAV boxes), main and branch supply duct traverse readings, outside/return air flow readings, exhaust air flow readings, water flow readings, amp readings, and water pressure drop readings through coils, heat exchangers, and or hydronic elements. For readings, a deviation of more than 10 percent between verification reading and reported data shall be considered as failing FPT. Readings that fail FPT shall require re-balancing.
- C. Participants (review of failed tests) shall include: CA, Owner, and TAB. Budget – 4 hours.

3.5 Building Power Outage Test:

- A. Participants shall include: CA, EC, CM, Owner, BAC, and MC. Budget - 4 hours total.
- B. Aspects of other functional performance tests will be done in concert with this test. Coordinate this test only after systems are ready for power outage tests.
- C. Simulate potential combinations of power outages reasonably possible.
 - 1. Simulate prolonged outage, at least 2 hours by opening main feeders.
 - 2. Simulate momentary outage by opening and closing main breakers as quickly as possible.
- D. While normal power is disconnected, survey facility for safe conditions and system operation as applicable.
- E. Return to normal power.

3.6 Air Handling Unit:

- A. Participants shall include: CA, MC (2), TAB (4), and BAC (8). (Hours indicated are for first of each AHU type for parties)
- B. Sample: 50-75 percent, Max Failure Limit: 10 percent
- C. CA shall review Start-Up Procedures and TAB reports.
- D. Verify automatic start/stop of fan and open/close of outdoor air damper.
- E. Manipulate control device to obtain maximum cooling and heating. Measure temperatures to determine capacity.
- F. Weather permitting, cause applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.

- G. Check calibration of control devices and for stable control response and component performance including cooling coils, heating coils, economizer cycles, and others. Ensure proper coordination of control loops and that no fighting or energy wastes result.
- H. Check for free and adequate flow of AC condensate.
- I. Ensure minimum required ventilation rates are maintained across full range of control (where applicable).
- J. Test interfaces with fire alarm system and smoke control sequences.
- K. Verify interlocks with exhaust fans where applicable.
- L. Test proof alarming where applicable.
- M. Test operation of applicable safeties including smoke detection, duct humidity, and others. Check AHU component status in each event.
- N. Check system status and operation in Off, Unoccupied, and Occupied modes of operation. Validate proper start up and shut down sequences.
- O. Simulate power outage and ensure automatic and orderly restart.

3.7 Fan Coil Unit:

- A. Participants shall include: CA, MC, TAB, and BAC. Budget 1 hour for first unit.
- B. Sample: 5 units or 20 percent, Max Failure Limit: 1 unit or 10 percent
- C. CA shall review Start-Up Procedures and TAB reports.
- D. Verify automatic start/stop of fan and open/close of outdoor air damper.
- E. Start heating and cooling system; manipulate control device to obtain maximum cooling and heating. Measure temperatures and pressures to determine capacity.
- F. Wear permitting; cause applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
- G. Check calibration of control devices and for stable control response.
- H. Check for free and adequate flow of AC condensate.
- I. Simulate power outage and ensure automatic and orderly restart.
- J. Verify changeover for two pipe systems.

3.8 Miscellaneous Terminal Unit:

- A. Participants shall include: CA, MC, TAB, and BAC. Budget 1 hour for first unit of each type.
- B. Sample: 5 units or 20%, Max Failure Limit: 1 unit or 10 percent
- C. CA shall review Start-Up Procedures and TAB reports.
- D. Verify automatic start/stop of fan and open/close of outdoor air damper as applicable.
- E. Start heating and cooling system; manipulate control device to obtain maximum cooling and heating. Measure temperatures and pressures to determine capacity.

- F. Wear permitting cause applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
- G. Check calibration of control devices and for stable control response.
- H. Check for free and adequate flow of AC condensate as applicable.
- I. Simulate power outage and ensure automatic and orderly restart.
- J. Verify changeover for two pipe systems as applicable.

3.9 Heat Recovery Wheels:

- A. Participants shall include: CA, MC (4), TAB (4), and BAC (4).
- B. Sample: 100 percent
- C. CA shall check Start-Up Procedure.
- D. Inspect installation visually for proper rotation and seal and undamaged media.
- E. Check cross contamination and re-entrainment testing results are done under applicable section.
- F. Check full sensible and latent recovery efficiency at peak summer conditions.
- G. With different wear conditions, check mode of control. In winter, check discharge loop control and make sure sensors are calibrated and that heating does not overshoot and require cooling. In mild conditions, ensure minimum rotation/recovery. In summer conditions, ensure maximum recovery.
- H. Measure purge air and leakage flow to ensure it is less than or equal to rating.
- I. Check frost protection override control loop.
- J. Test operation during power outage in context of associated air handler.

3.10 Fan/Air System:

- A. Participants shall include: CA, MC, TAB, and BAC.
- B. Sample: 5 units or 20 percent, Max Failure Limit: 1 unit or 10 percent
- C. CA shall review Start-Up Procedures and TAB reports.
- D. Verify start/stop control sequences.
- E. Check capacity of fan at maximum conditions.
- F. Cause applicable modes of operation using false loading where practical. Check proper sequence for switching modes and proper operation within a mode.
- G. Verify interlocks with exhaust fans where applicable.
- H. Test interfaces with fire alarm system and smoke control sequences.
- I. Test proof alarming where applicable.

J. Simulate power outage and ensure automatic and orderly restart.

3.11 Building Automation System:

- A. Participants shall include: CA and controls contractor (Time is typically included in individual systems. However an additional 8 hrs shall be for workstation and administrative aspects.)
- B. Refer also to Section 15995 for BAS Commissioning requirements.
- C. CA shall review Start-Up Procedure.
- D. Controls system sampling will typically correspond to sampling rate of a system or piece of equipment. These sampling rates are indicated above for respective item.
- E. Operate equipment and subsystems through specified modes of control and sequences of operation including full and part load conditions, and emergency conditions.
- F. Verify that equipment operates in accordance with design intent and approved control diagrams. This shall include checking operation of dampers, valves, smoke detectors; high and low limit controls, of a sample of 25 percent of components with a maximum failure limit of 10 percent.
- G. Analog Input (AI) Sensors: (at a sample of 50 percent of inputs on sampled devices (see above for device samples) with a maximum failure rate of 10 percent). Spot-check AI sensors (space temperature sensors, outside, return, and mixed air temperature sensors, discharge air temperature sensors, chilled water and hot water temperature sensors, and humidity sensors, air and water differential pressure sensors, airflow monitoring stations, etc.) for acceptable accuracy (which is generally as specified for device).
- H. Analog Outputs - Valves, Dampers and Actuators: (at a sample of 50 percent of inputs on sampled devices (see above for device samples) with a maximum failure rate of 10 percent) Ensure that valves, dampers and actuators close-off or seal against maximum pressure differential. Ensure that actuators stroke throughout correct range (correlated with programmed range) under operations pressures anticipated and that petitioners are set correctly where applicable.
- I. Establish trends of control system points for a minimum of a two week period prior to and throughout Acceptance period. Trends shall be analyzed to identify any control problems, lack of capacity, control loops fighting or unstable or operational anomalies.
- J. Automatic Switches: Spot-check (at a sample of 50 percent of inputs on sampled devices (see above for device samples) with a maximum failure rate of 10 percent) operation of automatic switches (pressure switches, current switches, flow switches, and others) to ensure that they are adjusted to proper make and break settings.
- K. Verify standalone functionality of controllers. Generally disconnect LAN communication wiring and ensure that controller functions properly and that loss of communication is acknowledged by interface. Restore communications and ensure an orderly restoration to normal control.
- L. Verify that BAS interface; BAS software, graphics and functions are in accordance with design intent and approved control diagrams.
- M. Check dial-in communications where applicable to ensure functionality.

END OF SECTION