

SECTION 01 9113 – COMMISSIONING OF HVAC, HVAC CONTROLS, DOMESTIC HOT WATER, LIGHTING CONTROLS, PHOTOVOLTAIC, BUILDING ENVELOPE, ELEVATORS, ACID WASTE PIPING, EMERGENCY POWER, FIRE ALARM and SECURITY

Note: The Unified Facilities Guide Specification Section 070523 was referenced for designating requirements of the pressure tests and infrared thermography listed in this specification section.

PART 1 - GENERAL REQUIREMENTS**1.1 SUMMARY****A. Section includes commissioning process requirements for the following systems:**

1. Building Envelope Systems
2. Laboratory and Building Relative Pressure
3. Elevators and Associated Features
4. HVAC
5. HVAC Controls
6. Domestic Hot Water
7. Acid Waste Piping
8. Lighting and Day Lighting Controls
9. Photovoltaic System
10. Emergency Power Distribution
11. Fire Alarm System
12. Security and Intrusion Detection

B. Related Sections: The following sections contain requirements that relate to this Section:

1. Drawings and general provisions of the Contract, including General and Supplementary Conditions, and other Division-1 Specification Sections, apply to work of this Section.
2. Owner's Project Requirements and Basis of Design documents can be made available upon request.
3. Section 013300 "Submittal Procedures" for submittal procedures requirements for commissioning.
4. Section 017300 "Execution" for requirements relating to cutting and patching requirements.
5. Section 017700 "Closeout Procedures" for certificate of Construction Phase Commissioning Completion submittal requirements.
6. Section 017823 "Operation and Maintenance Data" for preliminary operation and maintenance data submittal.
7. Section 070800 "Commissioning of Building Envelope" for commissioning requirements for building envelope systems.
8. Division 11 – Laboratory Equipment
9. Division 14 – Elevators
10. Section 140800 "Commissioning of Elevators" for commissioning requirements for conveying equipment.
11. Division 21 – Fire Suppression
12. Division 22 – Plumbing
13. Section 220800 "Commissioning of Domestic Hot Water Systems" for commissioning requirements for domestic hot water systems.
14. Division 23 – Heating, Ventilating, and Air-Conditioning
15. Section 230800 "Commissioning of HVAC systems" for commissioning requirements for HVAC.
16. Division 26 – Electrical
17. Section 260800 "Commissioning of Lighting, Photovoltaic, and Emergency Power Systems" for 1 commissioning requirements for electrical systems.
18. Division 27 – Communications

19. Division 28 – Fire Alarm
20. Division 28 – Security and Intrusion Detection
21. Section 280800 “Commissioning of Fire Alarm, Security and Intrusion Systems” for commissioning requirements for fire alarm, electronic safety and security systems.

C. Section Includes:

1. General requirements for coordinating and scheduling commissioning.
2. Commissioning meetings.
3. Commissioning reports.
4. Use of test equipment, instrumentation, and tools for commissioning.
5. Construction checklists, including, but not limited to, installation checks, startup, performance tests, and performance test demonstration.
6. Commissioning tests and commissioning test demonstration.
7. Adjusting, verifying, and documenting identified systems and assemblies.

1.2 REFERENCES

- A. AABC National Standards – 2002: *For Total System Balance*
- B. ACG Commissioning Guideline – 2005
- C. ANSI/ASHRAE/IES Standard 90.1 – 2013; *Energy Standard for Buildings Except Low Rise Residential Buildings (SI Edition)*
- D. ANSI/ASHRAE/IES Standard 189; *Standard for the Design of High-Performance Green Buildings*
- E. ASHRAE Guideline 0 – 2013; *Commissioning Process*
- F. ASHRAE Guideline 1.1 – 2007; *The HVAC&R Technical Requirements for the Commissioning Process*
- G. ASHRAE Guideline 202 – 2013; *Commissioning Process for Buildings and Systems*
- H. ASTM E779-2010 – Standard Test Method for Determining Air Leakage Rate by Fan Pressurization
- I. ASTM C1046-95(2013) – Standard Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components
- J. ASTM C1060-2003 – Standard Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings
- K. ASTM C1153-97(2003)e1 – Standard Practices for Location of Wet Insulation in Roofing Systems Using Infrared Imaging
- L. ASTM C1155-95(2013) – Standard Practices for Determining Thermal Resistance of Building Envelope Components from the In-Situ Data
- M. ASTM E1186-03(2009) – Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
- N. ASTM E1827-2011 – Standard Test Method for Determining Airtightness of Buildings Using an Orifice Blower Door

- O. BCA Best Practices in New Construction 2013
 - P. BICSI: Telecommunications Distribution Methods Manual, 11th Edition – 2006
 - Q. ICC G4 – 2012 Guideline for Commissioning
 - R. Infrared Training Center Infrared Thermography Certification Program
 - S. ISO 6781-1983: Thermal Insulation – Qualitative Detection of Thermal Irregularities in Building Envelopes – Infrared Method
 - T. ISO 10878-2013 Infrared Thermography – Non-Destructive Testing
 - U. NECA 90: Commissioning Building Electrical Systems – 2004
 - V. NFPA 70: National Electrical Code – 2008
 - W. National Institute of Building Sciences (NIBS) Whole Building Design Guide
 - X. National Institute of Building Sciences (NIBS) Guideline 3-2012 – Building Enclosure Commissioning (BECx) Process
 - Y. NFPA 72 – National Fire Alarm and Signaling Code
 - Z. USGBC LEED Reference Guide – Edition 2009
 - AA. 2013 Kentucky Building Code
- 1.3 DEFINITIONS
- A. Acceptance Criteria: Threshold of acceptable work quality or performance specified for a commissioning activity, including, but not limited to, construction checklists, performance tests, performance test demonstrations, commissioning tests and commissioning test demonstrations.
 - B. Air Leakage Rate: How leaky, or conversely how airtight a building envelope is. The air leakage is normally described in terms of airflow rate for the surface area of the envelope at a defined differential pressure.
 - C. Basis of Design: A document that records the concepts, calculations, decisions, and product selections used to meet the Owner’s project requirements and to satisfy applicable regulatory requirements, standards, and guidelines. The document includes both narrative descriptions and lists of individual items that support the design process.
 - D. Blower Door: Commonly used term for an apparatus used to pressurize and depressurize the space within the building envelope and quantify air leakage through the envelope. The blower door typically includes a door fan and an air resistant fabric or a series of hard panels that extends to cover and seal the door opening between the fan shroud and door frame. The door fan is a calibrated fan capable of measuring airflow and is usually placed in the opening of an exterior door. With the air barrier otherwise sealed, air produced by the door fan pressurizes or de-pressurizes the envelope, depending on the fan's orientation.
 - E. Checklists: Verification checklists that are developed and used during all phases of the commissioning process to verify that the Owner’s Project Requirements are being achieved. This includes checklists for general verification, plus testing, training, and other specific requirements.

- F. Commissioning: Commissioning is a process that enhances the delivery of a project by verifying and documenting that the facility and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner’s project requirements (design intent). In addition to uncovering deficiencies in design or installation using peer review and field verification.
- G. Commissioning Authority (CxA): The entity identified by the Owner who leads, plans, schedules, and coordinates the commissioning team to implement the commissioning process.
- H. Commissioning Plan: An overall plan developed by the commissioning agent that provides the structure, schedule and coordination planning for the commissioning process.
- I. Commissioning Report: The document prepared during the acceptance phase of the commissioning process after all functional performance tests are completed. It includes an executive summary, building description, the completed commissioning plan, and all documentation generated during the commissioning process along with completed commissioning test plans.
- J. Commissioning Team (CT): The individuals who through coordinated actions are responsible for implementing the commissioning process.
- K. Commissioning Technician (CxT): Commissioning personnel who work under the direction and supervision of the Commissioning Authority. The CxT implements tasks delineated by the Commissioning Plan and assigned by the CxA.
- L. Commissioning Provider Group (Cx PG): Commissioning personnel who work under the direction and supervision of the Commissioning Firm and the Commissioning Authority.
- M. Construction Phase Commissioning Completion: The stage of completion and acceptance of commissioning when resolution of deficient conditions and issues discovered during commissioning and retesting until acceptable results are obtained has been accomplished. Owner will establish in writing the date Construction Phase Commissioning Completion is achieved. See Section 017700 “Closeout Procedures” for certificate of Construction Phase Commissioning Completion submittal requirements.
1. Commissioning is complete when the work specified in this Section and related Sections has been completed and accepted, including, but not limited to, the following:
 - a. Completion of tests and acceptance of test results.
 - b. Resolution of issues, as verified by retests performed and documented with acceptance of retest results.
 - c. Comply with requirements in Section 017900 “Demonstration and Training.”
 - d. Completion and acceptance of submittals and reports.
- N. Exterior Enclosure: The exterior enclosure of a building includes all systems separating the interior environment from the exterior, including exterior walls, fenestration, and roofing and roof openings, below grade perimeter walls and the slab-on-grade or crawlspace.
- O. Functional Performance Test (FPT): Functional Performance Tests are performed on an individual component of a system to determine if that component independently performs the functions intended and produces the capacity specified.
- P. Negative Pressure Test (Depressurization Test): A test wherein the air inside the envelope is drawn to the outdoors. This places the envelope at a lower (negative) pressure with respect to the outdoors.
- Q. Owner’s Project Requirements (OPR): A written document that details the owner’s functional requirements of a project and the expectations of how it will be used and operated. This includes project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.
- R. Owner’s Witness: Commissioning Authority, Owner’s Project Manager, or Architect-designated witness authorized to authenticate test demonstration data and to sign completed test data forms.

- S. Pressure Test: A test in which the envelope is either pressurized or de-pressurized with respect to the outdoors.
- T. Positive Pressure Test (Pressurization Test): A test wherein the air is pushed into the envelope. This places the envelope at a higher (positive) pressure with respect to the outdoors.
- U. “Systems,” “Assemblies,” “Subsystems,” “Equipment,” and “Components”: Where these terms are used together or separately, they shall mean “as-built” systems, assemblies, subsystems, equipment, and components.
- V. Systems Manual: A system-focused composite document that includes the design and construction documentation, facility guide and operation manual, maintenance information, training information, Commissioning Process records, and additional information of use to the owner during occupancy/operations.
- W. Test Procedure: A written protocol that defines methods, personnel, and expectations for tests conducted on components, equipment, assemblies, systems, and interfaces among systems.
- X. Thermography: Use of the infrared camera to take thermal images with respective digital photographs of the exterior and interior building envelope surfaces while the blower door fans are operating in the positive and negative pressure mode.
- Y. Verification: Range of checks and tests carried out to determine whether components, subsystems, systems, and interfaces between systems operate in accordance with the construction documents.

1.4 DESCRIPTION OF WORK

- A. The purpose of the commissioning process is to provide the owner/operator of the facility with a high level of assurance that the commissioned systems have been installed in the prescribed manner, and operate within the performance guidelines set in Owner’s Project Requirements (OPR). The Commissioning Authority (CxA) shall provide the owner with an unbiased, objective view of the system’s installation, operation, and performance. This process is not intended to eliminate or reduce the responsibility of the design team or installing contractors to provide a finished product. Commissioning is intended to enhance the quality of system start-up and aid in the orderly transfer of systems for beneficial use by the owner. The CxA will be a member of the construction team, administrating and coordinating commissioning activities with the design team, general contractor, subcontractors, manufacturers and equipment suppliers.
- B. This commissioning specification has been included for reference to define contractors’ responsibilities. Each contractor should review this procedure and include adequate time in their proposal.

1.5 CxA SUBMITTALS

- A. Submit the following in accordance with Section 013300 Submittal Procedures:

No later than 60 days after completion of the pressure test and thermography, submit an organized report containing the BUILDING AIR BARRIER SYSTEM TEST REPORT, which contains the following elements:

1. Table of contents
2. Executive summary
3. Leakage rate test chart/graph
4. Field reports
5. Pressure test system verification checklist
6. Pressure test functional performance test
7. Thermographic Investigation Report
8. Appendices (Includes Testing Equipment and Calibration Certificates)

- B. Submit the following in accordance with Section 013300 Submittal Procedures:

No later than 60 days after completion of commissioning, submit the COMMISSIONING REPORT, which contains at least the following elements:

1. Table of contents
2. Executive summary
3. Field Reports
4. Resolution Tracking Form
5. Document Reviews (Submittals, Design, etc, as applicable)
6. Completed System Verification Checklists
7. Completed Functional Performance Tests

- C. Submit the following in accordance with Section 013300 Submittal Procedures:

During the building envelope kickoff meeting submit the following work plan and test procedures:

1. Memorandum of test procedure.
 - a. Proposed dates for conducting the pressure and thermographic tests.
 - b. Submit detailed pressure test procedures. Provide in the plan the proposed locations for installing the blower door(s) equipment.
2. List of test equipment to be used.
3. List of Contractor's support equipment that will be required to perform all tests.
4. Other Contractor's support personnel who will be on site for testing, as applicable.

1.6 INSTALLING CONTRACTORS CLOSEOUT SUBMITTALS

- A. Commissioning Report Supplemental Information:

1. At Construction Phase Commissioning Completion, provide the following:
 - a. Pre-startup reports
 - b. Startup reports
 - c. Approved test procedures
 - d. Test data forms, completed and signed
 - e. Controls point-to-point verification documentation
 - f. Preliminary test and balance report(s)
 - g. Progress reports
 - h. Commissioning issues reports showing resolution of issues
 - i. Correspondence or other documents related to resolution of issues
 - j. Other reports required by commissioning authority
 - k. List unresolved issues and reasons they remain unresolved and should be exempted from the requirements for Construction Phase Commissioning Completion
- B. Provide Certificate of Construction Phase Installation Readiness for Functional Performance Tests.
- C. Provide Operation and Maintenance Data: For proprietary test equipment, instrumentation, and tools to include in operation and maintenance manuals.
- D. Provide As-Built (Existing Conditions) Drawings and Documents.

1.7 COMPENSATION

- A. Should Architect, Commissioning Authority, or Owner's staff incur additional expenses due to actions of Contractor listed below, the Owner reserves the right to charge the Contractor for both time and mileage.
 - 1. Failure to provide timely notice of commissioning activities schedule changes.
 - 2. Failure to meet acceptance criteria for test demonstrations.

1.8 QUALITY ASSURANCE

1.8.1 Qualifications

1.8.1.1 Commissioning Authority

- A. The Commissioning Authority (CxA) is contracted directly with the owner, Murray State University for this project, and includes pressure tests and thermography services.

1.8.1.2 Pressure Test Agency

- A. Submit information certifying that the pressure test agency is an independent third party agency, not an affiliate or subsidiary of the prime contractor, subcontractors, equipment or material vendors, or A/E firm. The work of the pressure test agency is limited to pressure testing the building envelope, performing a thermography test and investigating, through various methods, the location of air leaks through the air barrier. See Paragraph 3.2 – PRESSURE AND THERMOGRAPHY TEST AGENCY for additional requirements. For thermographer qualifications, see paragraph 'Thermographer Qualifications'.
- B. The agency is to be regularly engaged in pressure testing of commercial/industrial building envelopes. If using blower door, the lead test technician must have at least two years of experience in using such equipment in building envelope pressurization tests. Formal training using pressure test equipment is highly recommended.

1.8.1.3 Thermographer Qualifications

- A. The thermographer must have at least two years of building science thermography experience in IR testing commercial or industrial buildings. The thermographer must also have experience in building envelopes and building science in order to make effective recommendations to the contractor should the envelope require additional sealing.
Submit the thermographer's Infrared Training Center Level I Certificate for approval. Submit a list of at least ten commercial/industrial buildings on which the thermographer has performed IR thermography in the past three years. The thermographer is to have a current active Level I certification.

1.8.1.3 Test Instruments and Date of Last Calibration

- A. Submit a signed and dated list of test instruments, application, manufacturer, model, serial number, range of operation, accuracy and date of most recent calibration.

1.9 CLIMATE CONDITIONS SUITABLE FOR PRESSURE TEST AND INFRARED THERMOGRAPHY

- A. As the test date approaches, monitor the weather forecast for the test site. Avoid testing on days forecast to experience high winds, rain, or snow. Monitor weather forecasts prior to shipping pressure test equipment to the site. Preferred ambient weather test conditions as stated in ASTM E779 are 0 to 4 mph

winds and an ambient temperature range of 41 to 95°F. Based on current and forecast weather conditions, the Commissioning Team will coordinate scheduling for the test to occur.

1.9.1 Rain

- A. Rain can temporarily seal roof and wall assemblies so that they leak less than under no-rain conditions. Do not test during rain or if rain is anticipated during testing. If pneumatic hoses are installed and exposed to rain observe the hose to insure rainwater has not migrated into the hose ends. Orient all exposed hose ends to keep them out of water puddles. Success in temporarily sealing outdoor ventilation components such as louvers and exhaust fans may also be compromised by rain. Don't seal roof-mounted ventilation components during times of potential lightning.

1.9.2 Snow

- A. Snow piled against a wall or on top of a roof can make a building envelope appear to be more airtight than it actually is. Snow may also impact thermography readings. Remove snow from around and on top of the building prior to testing.

1.9.3 Wind

- A. Because wind can skew pressure test results, test only on days and times when winds are anticipated to be the calmest. Avoid pressure testing during gusty or high wind conditions.

PART 2 - PRODUCTS

2.1 Pressure Test and Infrared Thermography Equipment

- A. The testing agency is to supply sufficient quantity of blower equipment that will produce a minimum of 75 Pa differential pressure between the envelope and outdoors using the test methods described herein. Supplying additional blower test equipment to provide additional airflow capacity or to act as a backup is highly recommended.

2.1.1 Blower Door Fans

- A. Each airflow measuring system including blower door fans are to be calibrated within the last 3 years in accordance with ASTM E1827. Calibrated blower door fans must measure accurately to within plus or minus 5 percent of the flow reading. Blower door equipment and trailer mounted fans are to be specifically designed to pressurize building envelopes. Each set of blower door equipment is to include fan(s), digital gage(s), door frame, door fabric or hard panels.

2.1.2 Digital Gages as Test Instruments

- A. Use only digital gages as measuring instruments in the pressure test; analog gages are not acceptable. The gauges must be accurate to within 1.0 percent of the pressure reading or 0.15 Pa, whichever is greater. Each gage is to have been calibrated within two years of the test. The calibration is to be checked against a National Institute of Standards and Technology (NIST, formerly National Bureau of Standards) traceable standard.

2.2 Thermal Imaging Infrared Camera Requirements

- A. The thermal imaging infrared camera used in the thermography test must have a thermal sensitivity (Noise Equivalent Temperature Difference.) of +/- 0.2°F at 18°F at 86°F or less. The camera's operating

spectral range must fall between 2 and 15 micrometers. The camera's IR image viewing screen resolution must measure at least 240x180 pixels. The camera must have a means of recording thermal images seen on the camera viewing screen. The camera is to display output as individual still frame images that also can be downloaded and inserted into an electronic Thermographic Investigation Report. Submit camera make and model, and catalog information that defines the camera thermal sensitivity for approval.

PART 3 - EXECUTION

3.1 ROLES OF THE COMMISSIONING AUTHORITY

- A. The primary responsibility is to inform the owner, the design team, and the construction team of the status, integration, and performance of commissioned systems within the facility.
- B. The CxA shall function as a catalyst and initiator to disseminate information and assist the design and construction teams in implementing completion of the construction process. This shall include system verification, functional performance testing, and conformance with the intended design of each system. Services include documenting construction observations, verification and functional performance testing, and documenting proper distribution of performance and operating information to the owner's O&M staff.
- C. The CxA shall assist the responsible parties in maintaining a high quality installation by meeting or exceeding prevailing standards and specifications.
- D. The CxA shall observe and coordinate testing as required to assure system performance meets the design intent.
- E. The CxA shall document the results of the performance testing directly and/or assure that the appropriate technicians document testing. The CxA shall approve standard forms to be used by all parties for consistency of approach and type of information to be recorded.
- F. The CxA shall provide technical expertise to oversee and verify the correction of deficiencies found during the commissioning process.
- G. The CxA is to remain an independent party with specific knowledge of commissioned systems on the project. The CxA shall investigate the scope and extent of the problem and facilitate communication to determine responsibilities by delineating specifications. The CxA shall monitor resolution for conformance with design intent and prevailing industry standards.
- H. The CxA shall document the date of acceptance as determined by the general contractor, owner and design team. System Verification Checklists and Functional Performance Test results may be used in determining the start of the warranty period for commissioned systems and subsystems.
- I. The CxA will review operating and maintenance materials for commissioned systems.
- J. The CxA will review phasing plans as provided by the General Contractor relating to temporary use of HVAC equipment, O&M considerations, warranty issues, impact of construction sequencing on occupied areas, and interruption of services from the existing equipment.

3.2 PRESSURE AND THERMOGRAPHY TEST AGENCY

- A. Execute building air leakage diagnostic testing by fan pressurization for quantitative analysis and correlated thermography for qualitative analysis per ASTM E779 and ASTM C1060/ISO 6781, respectively.

3.2.1 Field Work

- A. The lead pressure test technician and thermographer are to be present at the project site while testing is performed and are to be responsible for conducting and supervising their respective test work under management of the Commissioning Authority.

3.2.2 Reporting Work

- A. The lead pressure test technician and thermographer present at the project site while testing is performed are to be responsible for conducting, supervising, and reporting of their respective test work under management of the Commissioning Authority.
- B. The lead pressure test technician is to prepare, sign, and date the test agenda, equipment list, and submit a Air Leakage Test Report. The thermographer is to prepare, sign, and date the test agenda, equipment list, and submit a Thermographic Investigation Report. These reports are contained in the BUILDING AIR BARRIER SYSTEM TEST REPORT detail in Section 1.5.

3.3 ENVELOPE SURFACE AREA CALCULATION

- A. The architectural air barrier boundary includes the floor (slab on grade), exterior walls, and roof/ceiling. After construction of the air barrier envelope is complete, the contractor is to measure the envelope to ensure the physical measurements match the design drawings that the air barrier envelope surface area calculations are based on. If the measurements are not consistent with the defined air barrier boundary as indicated, re-calculate the envelope surface area and submit the envelope surface area calculation and results for review by the Designer of Record. If the air barrier was defined during design but the air barrier envelope surface area was not calculated, calculate it during construction and submit the envelope surface area calculations and result for review by the Designer of Record.

3.4 PREPARING THE BUILDING ENVELOPE FOR THE PRESSURE TEST

- A. Testing During Construction

The pressure test cannot be conducted until components of the air barrier system have been installed. After sealing as described in related sections has been completed, the installer and CxA will observe the envelope to ensure it has been adequately prepared. During the pressure test, stop all ongoing construction within and neighboring the envelope, which may impact the test or the air barrier integrity. The pressure test may be conducted before finishes that are not part of the air barrier envelope have been installed. For example, if suspended ceiling tile, interior gypsum board or cladding systems are not part of the air barrier the test can be conducted before they are installed. Testing prior to installing the finished ceilings within the envelope and immediately surrounding it is recommended. The absence of finished ceilings allows for observation and diagnostic testing of the roof/wall interface and for implementation of repairs to the air barrier, if necessary, to comply with the maximum allowed leakage.

- B. Sealing the Air Barrier Envelope

Installers shall seal penetrations through the air barrier. Unavoidable penetrations due to electrical boxes or conduit, plumbing, and other assemblies that are not airtight are to be made so by sealing the assembly and the interface between the assembly and the air barrier or by extending the air barrier over the assembly. Support the air barrier so as to withstand the maximum positive and negative air pressure to be placed on the building without displacement or damage. The Contractor shall durably construct the air barrier to last the anticipated service life of the assembly and to withstand the maximum positive and negative pressures placed on it during pressure testing.

C. Minimize Potential for Blowing Dust and Debris

Because high velocity air may be blown into and out of the envelope during the test, debris, including dust and litter, may become airborne, debris may become trapped or entangled in test equipment, thereby skewing test results and possibly damaging the test equipment. Areas within and surrounding the envelope are to be free of dust, litter and construction materials that are easily airborne. If pressurizing existing, occupied areas, provide adequate notice to building occupants of blowing dust and debris, and general disruption of normal activities during the test.

D. Installing Blower Door Equipment in a Door Opening

Where blower door fans are used, before installing blower door equipment, select a door opening that does not restrict air flow into and out of the envelope and has at least 5 feet clear distance in front of and behind the door opening. Disconnect the door actuator and secure the door open to prevent it from being drawn into the fan by suction pressure.

E. Other Requirements for Preparing for Pressure Test

Reference section 3.12.I for other items the contractor will perform prior to and after the pressure testing.

3.5 BUILDING ENVELOPE AIR TIGHTNESS REQUIREMENT

- A. The purpose of the pressure (air leakage) test is to determine final compliance with the airtightness requirement by demonstrating the performance of the continuous air barrier. An effective air barrier envelope minimizes infiltration and exfiltration through unintended air paths (leaks).

3.5.1 Architectural Only Test Envelope

- A. The test envelope is the architectural air barrier boundary as defined on the construction drawings. This boundary includes connecting exterior walls, roof and floor (slab on grade), which comprise a complete, whole, and continuous three dimensional envelope. Perform both a positive pressure test and a negative pressure test on this envelope, unless otherwise directed.

3.5.1.1 Architectural Only Envelope Test Goal

- A. Input data from the test into the Air Leakage Rate by Fan Pressurization spreadsheet as described in Paragraph 3.7 – CALCULATION PROGRAM via the Air Leakage Test Form. Compare output from the spreadsheet against the maximum allowable leakage defined in Section 3.11.J – Functional Performance Tests. The Architectural Only Envelope passes the test if the leakage rate, as calculated using the spreadsheet, is equal to or lower than the leakage rate goal defined in Section 3.11.J, and if the Architectural Plus HVAC System Test Envelope is not applicable.

3.5.2 Architectural Plus HVAC System Test Envelope

- A. This test envelope includes the architectural air barrier boundary as defined on the construction drawings plus all HVAC supply, return and exhaust systems that penetrate and terminate within said architectural air barrier boundary and that extends outward from said boundary. All associated ductwork, intake and exhaust dampers, and air moving devices, including air handling units and fans, are included in this test envelope even if they are physically located outside of the architectural air barrier boundary. The boundary extends to and includes the low leakage intake and exhaust dampers. Perform both a positive pressure test and a negative pressure test on this envelope, unless otherwise indicated.

3.5.2.1 Architectural Plus HVAC System Envelope Test Goal

- A. Data from the test is to be input into the Air Leakage Rate by Fan Pressurization spreadsheet as described in Paragraph 3.7 – CALCULATION PROGRAM via the Air Leakage Test Form found in Appendix C. If both a positive and negative pressure tests were performed, both data sets are to be input into the spreadsheet. Compare output from the spreadsheet against the leakage rate goal. The Architectural Plus HVAC System Test Envelope passes the test if the leakage rate, as calculated using the spreadsheet, is equal to or lower than the leakage rate goal defined in Section 3.11.J.

3.6 LOCATING LEAKS BY DIAGNOSTIC TESTING

Use diagnostic test methods described herein to discover obvious leaks through the envelope. Perform diagnostic tests on the building envelope regardless of the envelope meeting or failing to meet the designated leakage rate goal. Use diagnostic test methods in accordance with ASTM E1186 and in conjunction with pressurization equipment as necessary. Use the thermography diagnostic test to establish a baseline for envelope leakage. Using a variety of diagnostic tests may help locate leaks that would otherwise go undetected if only a single diagnostic test were used. Pay special attention to locating leaks at interfaces where there is a change in materials or a change in direction of like materials. These interfaces, at a minimum, include roof/wall, wall/wall, floor/wall, wall/window, wall/door, wall/louver, roof mounted equipment/roof curb interfaces and all utility penetrations (ducts, pipes, conduits, etc) through the envelope's architecture. Also use diagnostic tests to check for leakage between the air duct and duct damper, when the damper, under normal control power, is placed in the closed position. Should leaks be discovered during diagnostic tests, thoroughly document their exact locations on a floor plan so that sealing can be later applied. If the envelope passes the leakage test, use the diagnostic test procedure described above to identify obvious leakage locations. Seal the leaks at the discretion of the the Designer of Record based on the magnitude, location, potential for liquid moisture penetration or retention, potential for condensation, presence for condensation, presence of daylight through an architectural surface or if the leakage location could potentially cause rapid deterioration or mold growth of, or in the building envelope materials and assemblies. Installer shall apply sealing measures after diagnostic testing is complete and all pressurization blowers are off. To verify that the applied sealing measures are effective, re-test for leaks using the same diagnostic methods that discovered the leak. Reseal and retest until the envelope meets the leakage rate goal and all obvious leaks through the envelope are sealed.

3.6.1 Infrared Thermography Test

- A. Coordinate thermography examination with the pressure test agency and the test agency's pressurization equipment as directed by the CxA. The pressure test agency is to allow adequate time for the thermographer to perform a complete thermographic examination, as described hereinafter, of the envelope interior under negative relative pressure conditions and exterior under positive relative pressure conditions.

3.6.1.1 Thermography Testing of the Air Barrier

- A. Test the building envelope in accordance with ISO 6781, ASTM C1060 and ASTM E1186. Perform a complete thermographic observation consisting of the full observation of the interior and exterior of the complete air barrier envelope. Document envelope areas that are inaccessible for testing. Use infrared thermography technology in concert with standard pressurization methods to locate leaks through the air barrier. Because thermography works best with at least an 18°F temperature difference between the envelope interior and the exterior, adjust the HVAC system if possible, to create or enhance this temperature difference. The minimum allowable temperature difference is 3°F. Maintain this temperature difference for at least 3 hours prior to the test. Use pressurization methods to establish a minimum of +20 Pa pressure difference with respect to the outdoors while using an infrared camera to view the envelope

from outdoors. When viewing the camera from inside the envelope, keep the envelope at a pressure differential of -20 Pa with respect to the outdoors using pressure test equipment.

3.7 CALCULATION PROGRAM

- A. To calculate the envelope leakage rate and other required outputs, input the data obtained during the pressure tests as documented in the Air Leakage Test Form (Appendix C) into the Air Leakage Rate by Fan Pressurization Excel spreadsheet. This spreadsheet can be found at the following website:

<http://wbdg.org/ccb/NAVGRAPH/graphdoc.pdf>.

3.8 AFTER COMPLETION OF THE PRESSURE AND/OR DIAGNOSTIC TEST

- A. After all pressure and/or diagnostic testing has been completed the Contractor will unseal all temporarily sealed items. Under direction of the Contractor, return all dampers, doors, and windows to their pre-test conditions. The Contractor shall remove taps and plastic from all temporarily sealed openings, being careful not to deface painted surfaces. If paint is removed from finished surface, the Contractor will repaint to match existing surfaces. Return all fans and air handling units to pre-test conditions. Reference section 3.12.I for other items the contractor will perform after the pressure testing.

3.9 REPAIR AND PROTECTION

- A. Repair and protection is the Contractor's responsibility, regardless of the assignment of responsibility for testing, observation, and similar services. Upon completion of observation, testing, or sample taking and similar services, repair damaged construction and restore substrates and finishes, protect construction exposed by or for quality control service activities, and protect repaired construction.

3.10 SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS

- A. Exterior Building Envelope Systems
 1. Exterior Enclosure (vertical, above grade): Exterior Walls, Exterior Windows, Exterior Doors, Connections to Existing Buildings, Louvers and Vents, Grilles and Sunscreens, Sealants and expansion joints, control joints, flashings, plaza decks, and other special building exterior enclosure systems, equipment and controls.
 2. Roofing: Roof System including parapet, Roof Openings including skylights, pipe chases, ducts, wire ways, etc.
 3. Building Air Leakage Tests
 4. Thermography
- B. Elevators and Associated Features
- C. Laboratory and Building Relative Pressure
- D. Custom Air-Handling Systems
- E. Air Terminal Units
- F. Steam Boiler
- G. Cooling Towers
- H. Centrifugal Water Chillers

- I. Hydronic Pumps
 - J. Computer-Room Air-Conditioners
 - K. Fan Coil Units
 - L. Radiant Ceiling Panels
 - M. Unit Heaters
 - N. Mixed Flow, Induced Dilution Exhaust Fans
 - O. Exhaust Fans
 - P. Temperature and Air Flow Control Systems
 - Q. Building Automation Systems (BAS)
 - R. Domestic Hot Water System (DHW)
 - S. Acid Waste Piping
 - T. Lighting and Day Lighting Controls
 - U. Photovoltaic System
 - V. Fire Alarm System
 - W. Security and Intrusion System
 - X. Emergency Power/Transfer Switch Responses
- 3.11 CONTRACTOR SCHEDULING
- A. Commence commissioning as early in the construction period as possible.
 - B. Commissioning Schedule: Integrate commissioning into Contractor's construction schedule. See Section 013200 "Construction Progress Documentation."
 - 1. Include detailed commissioning activities in monthly updated Contractor's construction schedule and short interval schedule submittals.
 - 2. Schedule the start date and duration for the following commissioning activities:
 - a. Submittals.
 - b. Preliminary operation and maintenance manual submittals.
 - c. Installation checks.
 - d. Startup, where required.
 - e. Performance tests.
 - f. Performance test demonstrations.
 - g. Commissioning tests.
 - h. Commissioning test demonstrations.
 - 3. Schedule shall include a line item for each installation check, startup, and test activity specific to the equipment or systems involved.

4. Determine milestones and prerequisites for commissioning. Show commissioning milestones, prerequisites, and dependencies in monthly updated critical-path-method construction schedule and short interval schedule submittals.
- C. Two-Week Look-Ahead Commissioning Schedule:
1. Two weeks prior to the beginning of tests, submit a detailed two-week look-ahead schedule. Thereafter, submit updated two-week look-ahead schedules weekly for the duration of commissioning.
 2. Two-week look-ahead schedules shall identify the date, time, beginning location, Contractor personnel required, and anticipated duration for each startup or test activity.
 3. Use two-week look-ahead schedules to notify and coordinate participation of Owner's witnesses.
- D. Owner's Witness Coordination:
1. Coordinate Owner's witness participation via Architect.
 2. Notify Architect of commissioning schedule changes at least one week in advance for activities requiring the participation of Owner's witness.

3.12 COMMISSIONING PLAN

A. Commissioning Team

1. The Commissioning Team (CT) shall consist of key parties involved in design, construction and testing of this facility. It is necessary for each agency to appoint team members that will have long-term commitments to this project. Switching team members during the project will reduce the ability of the CT to provide continuity and acceptable results to the building owner. Team members must maintain an ongoing supervisory position on this project. One team member shall be provided by each of the parties listed below:
 - a. Owner – American Building College (ABC)
 - b. Division of Engineering and Contract Administration (DECA)
 - c. Architect – XYZ Architects (XYZA)
 - d. Design Engineer – XYZ Engineers (XYZE)
 - e. Commissioning Authority (CxA)
 - f. General Contractor (GC)
 - g. Elevator Contractor (ELC)
 - h. Mechanical Contractor (MC)
 - i. Sheet Metal Contractor (SMC)
 - j. Test and Balance Contractor (TABC)
 - k. Temperature Controls Contractor (TCC)
 - l. Electrical Contractor (EC)
 - m. Emergency Power Equipment Contractor (EPEC)
 - n. Lighting Controls Equipment Contractor (LCEC)
 - o. Photovoltaic Contractor (PVC)
 - p. Plumbing Contractor (PC)
 - q. Fire Alarm Contractor (FAC)
 - r. Security System Contractor (SSC)
 - s. Building Envelope Contractors

B. Owner's Project Requirements and Basis of Design Documents

1. The Owner's Project Requirements (OPR) is a written document prepared by the owner and the design team that details the functional requirements of a project and the expectations of how it will be used and operated. These include project goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information.
 2. The Basis of Design (BOD) is a document prepared by the design team that record the concepts, calculations, decisions, and product selections used to meet the Owner's Project Requirements and to satisfy applicable regulatory requirements, standards, and guidelines. This instrument contains narrative descriptions and supporting documentation.
- C. The CxA will review the OPR and BOD documents for commissioning provisions, functional performance, optimizing of performance, accessibility, TAB provisions, and O&M considerations.
- D. Commissioning Meetings
1. Commissioning meetings will be held in conjunction with progress meetings as necessary. The CxA will be on site for the Cx meetings. Commissioning meetings will be used to address any problems that alter the design intent or affect the commissioning process. These meetings provide an open forum for exchange of ideas between contractors, vendors, designers, users and owners. These meetings will be held in conjunction with progress meetings and/or contractor coordination meetings to avoid extra mobilization costs. Site observation walkthroughs by the CxA will be coordinated in conjunction with the commissioning meetings or separately as required to implement the commissioning process.
- E. Resolution Tracking Forms (RTF)
1. The use of Resolution Tracking Forms is a method employed by the CxA to monitor and record problems, their causes, and solutions. The use of these lists promotes communication between the installing contractors, design team, commissioning agent, and owner, in order to expedite their resolution in a timely manner.
 2. The CxA will regularly submit RTF's to the CT in order to document and resolve deficiencies as quickly as possible. The frequency of RTF submission will be adjusted as project conditions dictate.
- F. Submittal Reviews
1. The CxA will review contractor submittals that apply to systems being commissioned for compliance with the owner's project requirements and basis of design, concurrent with the architect or engineer of record.
- G. Systems Manual
1. The CxA or other project team members must develop a systems manual that provides future operating staff the information needed to understand and optimally operate the commissioned systems of the project.
- H. System Verification Checklists (SVC's) / Manufacturers' Checklists
1. The CxA will write SVC's based on the contract documents. These tests will be created for systems and subsystems. See *SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS*. Draft copies will be submitted to the CT for review and comment prior to placement on the job site. A master copy of the SVC's will be bound in a three-ring binder and placed on the job site for use by the installing contractors. No system will be started until the appropriate SVC's have been completed.

2. The CxA will review the SVC for each piece of equipment prior to start-up. Equipment will be released for start-up only after these checklists have been completed by the installing contractor and reviewed by the CxA.
3. The equipment manufacturers' checklists must also be reviewed by the CxA prior to start-up. These lists must be completed by the installing contractor, and reviewed by the CxA before start-up can commence.

I. Start-Up

1. Start-up of major commissioned systems will be witnessed the CxA. The appropriate contractors and/or manufacturer's representative will be required on site to perform start-up. No system will be started until the appropriate SVC's have been completed. No system will be started until the Manufacturer's checklists have been completed. Start-up will be performed according to the Manufacturer's recommended procedures. The CxA will visit the site to review completeness of installation in conjunction with progress meetings prior to starting commissioned equipment.
2. CT members involved in installation, fabrication, manufacture, control, or designer of equipment are required to be present at the time of start-up. A factory-authorized technician will be on site to start equipment when required by the specifications. This will minimize delays in bringing equipment on line and expedite acceptable functional performance in accordance with the OPR.

J. Functional Performance Tests (FPT's)

1. The CxA will write FPT's based on the OPR. These tests will be created for systems and subsystems. See SYSTEMS INCLUDED IN THE COMMISSIONING PROCESS above.
2. Each commissioned system(s) will be tested. A random sample of each subsystem will be tested. This will be coordinated and witnessed by the CxA and the owner's maintenance staff. Witnessing the FPT's will serve as a compliment to the O&M Training. No FPT's will be performed until the system and related subsystems have been started, the TAB report has been submitted and reviewed, and the completion of the control system has been documented through point-to-point checklists and other documentation.
3. The Functional Performance Tests shall include the Building Envelope, Elevators, HVAC, Domestic Hot Water, Acid Waste Piping, Lighting Controls, Photovoltaic, Fire Alarm, Security, and Emergency Power and related equipment.
 - a. Building Envelope/Air Barrier Systems (Roof, Walls & Floors) will be tested by the contractor and witnessed by the CxA in accordance with construction documents to achieve conformance with the OPR and the ASTM C1060, E779, E1827 Standards for Blower Door and Thermography Testing.
 - i. Building Air Leakage Tests will be conducted in accordance with ASTM E779 to document conformance with maximum allowable building air leakage of 0.25 CFM/SQ.FT. @ 75 Pa for the continuous air barrier installation.
 - ii. Thermography will be conducted in conjunction with building air leakage tests and according to ISO 6781 to qualitatively characterize the door blower test results by ASTM E779 methods.
 - b. The elevator trade representative will demonstrate to the CxA design intent conformance of elevator operation and with the CxA present the elevator trade representative will verify proper operation of commissioned systems before, during, and after transfer of emergency power.
 - c. Laboratory Rooms will be tested by measuring face velocities at fume hoods and checking relative room and building pressurization for conformance to DID.

- d. Custom Air-Handling Systems will be will be tested in designed operating modes. Proper operation will be verified at minimum OA, maximum OA, automatic control, and other modes, if necessary, to achieve OPR and BOD conformance.
 - e. Air Terminal Units will be tested at minimum and maximum airflow setpoints, and under automatic control. Intermediate settings will be tested as necessary.
 - f. Steam Boiler will be tested for conformance to OPR/BOD and relevant operating conditions.
 - g. Cooling Towers will be tested for conformance to OPR/BOD and relevant operating conditions
 - h. Centrifugal Water Chillers will be tested for conformance to OPR/BOD and relevant operating conditions
 - i. Hydronic Pumps will be tested under relevant operating conditions.
 - j. Computer-Room Air-Conditioners will be tested at minimum and maximum airflow setpoints, and under automatic control. Intermediate settings will be tested as necessary.
 - k. Radiant Ceiling Panels will be tested for conformance to OPR and BOD.
 - l. Unit Heaters will be tested for conformance to OPR and BOD.
 - m. Mixed Flow, Induced Dilution Exhaust Fans will be tested for conformance to OPR and BOD.
 - n. Exhaust Fans will be tested for conformance to OPR and BOD.
 - o. HVAC systems will be tested to assure that the building as an integrated system operates properly, and to verify that interlocks and interactions between new and existing equipment and systems function according to design intent.
 - p. Domestic Hot Water systems will be tested in designed modes under relevant operating conditions for conformance to OPR and BOD.
 - q. Acid Waste Piping will be tested for conformance to OPR and BOD.
 - r. Lighting Controls will be tested to assure that the building as an integrated system operates properly.
 - s. The appropriate contractors and vendors will demonstrate that the photovoltaic wiring, equipment, and systems are installed, operating, and functional in accordance with contract drawings and the Owner's Project Requirements.
 - t. The fire alarm trade representative will demonstrate to the CxA design intent conformance of fire alarm system operation and with the CxA present the fire alarm trade representative will verify proper operation of commissioned systems before, during, and after transfer of emergency power.
 - u. The security system trade representative will demonstrate to the CxA design intent conformance of fire alarm system operation and with the CxA present the security system trade representative will verify proper operation of commissioned systems before, during, and after transfer of emergency power.
 - v. The electrical trade representative will demonstrate to the CxA design intent conformance of emergency power operation and with the CxA present the electrical trade representative will verify proper operation of commissioned systems noted above before, during, and after transfer of emergency power.
4. Off-season mode testing will be implemented as necessary to assure conformance with the OPR. Installing contractors will be expected to participate as required by the project specifications.

K. Building Turn-Over / Owner Orientation / User Training

- 1. The CxA will assist contractors in preparing, coordinating and reviewing O&M manuals, working closely with each contractor to achieve specificity and completeness.
- 2. The CxA will review as-built drawings, working closely with each contractor to achieve specificity and completeness.

3. Owner training will be coordinated with the assistance of the CxA. The installing contractor will provide the training, or manufacturer's representative. The CxA will witness this training. This training should include both classroom training and hands-on operational training. The owner may choose to videotape this training for future use. The CxA will visit the site during the Turnover and Training period to assure that any on-going problems related to commissioned systems are being addressed and corrected in a timely and efficient manner.
4. The CxA will assist the owner/user with warranty issues.
5. The CxA will assist in the coordination of off-season testing, calibrating, and servicing as specified in the contract documents.

L. Warranty Review

1. The CxA will participate in a near end of warranty walk-through and review meeting to observe the operation of the commissioned systems. The following items will be reviewed and discussed: warranty issues, energy usage, maintenance practices, usage changes, and chronic problems, as well as other issues affecting the owner and the operation of the commissioned systems.

3.13 ROLES AND RESPONSIBILITIES OF INSTALLING CONTRACTORS

A. Installing Contractor Roles

1. General Contractor (GC)
2. Mechanical Contractor (MC)
3. Sheet Metal Contractor (SMC)
4. Test and Balance Contractor (TABC)
5. Temperature Control Contractor (TCC)
6. Elevator Contractor (ELC)
7. Electrical Contractor (EC)
8. Emergency Power Equipment Contractor (EPEC)
9. Lighting Controls Equipment Contractor (LCEC)
10. Photovoltaic Contractor (PVC)
11. Plumbing Contractor (PC)
12. Fire Alarm Contractor (FAC)
13. Security System Contractor (SSC)
14. Glazing Contractor (GLC)
15. Veneer/Masonry Contractor (VC)
16. Sealant Contractor (SC)
17. Sheathing Contractor (SHC)
18. Waterproofing Contractor (WC)
19. Insulation Contractor (IC)
20. Wall Panels Contractor (WPC)
21. Air Barrier Membrane Contractor (ABC)
22. Roofing Contractor (RC)
23. Fire Protection Contractor (FPC)
24. Exterior Enclosure Manufacturer Representatives (MR's)

B. General Contractor Responsibilities (GC)

1. Assure acceptable representation, with the means and authority to prepare and coordinate execution of the commissioning program as described in the contract documents.
2. Assure that the CxA shall receive a copy of all construction documents, addenda, change orders and appropriate approved submittals and shop drawings for review and use in development of the commissioning plan.

3. Coordinate inclusion of commissioning activities in the construction schedule.
4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
5. Facilitate resolution of deficiencies identified by observation or performance testing.

C. Mechanical Contractor Responsibilities (MC)

1. Include requirements for submittal data (including partial load data), O&M data, and training in each purchase order or sub-contract.
2. Assure cooperation and participation of specialty sub-contractors such as sheet metal, piping, refrigeration, water treatment, temperature controls, and TAB in commissioning activities.
3. Assure participation of major equipment manufacturers in appropriate startup, training, and testing activities.
4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
5. Attend commissioning meetings scheduled by the CxA.
6. Assist the CxA in system verification and performance testing.
7. Prepare preliminary schedule for commissioned system inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, system verification, performance testing, and system completion for use by the CxA. Update schedule as appropriate throughout the construction period.
8. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned equipment.
9. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
10. Notify the CxA a minimum of two weeks in advance of scheduled system start-up.
11. Update drawings to as-built condition and review with the CxA throughout the construction process.
12. Schedule vendor and subcontractor provided training sessions as required by project specifications.
13. Provide written notification that the following work has been completed in accordance with the project specifications, and that the equipment, systems and sub-systems are operating in accordance with design intent.
 - a. HVAC equipment including fans, energy recovery units, ductwork, dampers, heat pumps, etc.
 - b. Fire detection and smoke detection devices furnished under other divisions as they affect the operation of the HVAC systems.
 - c. That BAS is functioning in accordance with design intent.
 - d. Domestic Hot Water.
14. Participate in the Functional Performance Tests as required to achieve design intent.
15. Participate in the off-season mode testing as required to achieve design intent.
16. Participate in O&M Training as required by project specifications.
17. Provide a complete set of as-built drawings and O&M manuals for review.

D. Sheet Metal Contractor Responsibilities (SMC)

1. Include requirements for submittal data (including partial load data), O&M data, and training in each purchase order or sub-contract.
2. Assure cooperation and participation of specialty sub-contractors such as piping, refrigeration, water treatment, temperature controls, and TAB in commissioning activities.
3. Assure participation of major equipment manufacturers in appropriate startup, training, and testing activities.

4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
5. Attend commissioning meetings scheduled by the CxA.
6. Assist the CxA in system verification and performance testing.
7. Prepare preliminary schedule for commissioned system inspections, O&M manual submission, training sessions, pipe and duct system testing, flushing and cleaning, equipment start-up, system verification, performance testing, and system completion for use by the CxA. Update schedule as appropriate throughout the construction period.
8. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned equipment.
9. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
10. Notify the CxA a minimum of two weeks in advance of scheduled system start-up.
11. Update drawings to as-built condition and review with the CxA throughout the construction process.
12. Schedule vendor and subcontractor provided training sessions as required by project specifications.
13. Provide written notification that the following work has been completed in accordance with the project specifications, and that the equipment, systems and sub-systems are operating in accordance with design intent.
 - a. HVAC equipment including fans, energy recovery units, ductwork, dampers, heat pumps, etc.
 - b. Fire detection and smoke detection devices furnished under other divisions as they affect the operation of the HVAC systems.
14. Participate in the Functional Performance Tests as required to achieve design intent.
15. Participate in the off-season mode testing as required to achieve design intent.
16. Participate in O&M Training as required by project specifications.
17. Provide a complete set of as-built drawings and O&M manuals for review.

E. Test and Balance Contractor Responsibilities (TABC)

1. Attend commissioning meetings scheduled by the CxA.
2. Submit the TAB procedures and preliminary TAB report to the CxA for review at least two weeks prior to beginning TAB work.
3. Notify the CxA a minimum of two weeks in advance of scheduled TAB work.
4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
5. Provide partial, preliminary TAB Reports by phase, by building section, by system, or as required by the CxA.
6. Assist the CxA in system verification and performance testing.
7. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
8. Participate in verification of the TAB report, which will consist of repeating any selected measurement contained in the TAB report where required by the CxA for verification or diagnostic purposes.
9. Participate in the Functional Performance Tests as required to achieve design intent.
10. Provide sound and vibration measurements where required to assist in diagnosis of areas exhibiting unacceptable levels of noise or vibration.
11. Participate in the off-season mode testing as required to achieve design intent.
12. Participate in O&M Training as required by project specifications.

F. Temperature Control Contractor Responsibilities (TCC)

1. Review control sequence and component selection for conformance with design intent.
 - a. Verify that specified safeties and interlocks have been selected.
 - b. Verify proper selection of control valves and actuators based on design parameters.
 - c. Verify proper selection of control dampers and actuators based on design parameters.
 - d. Verify that sensor selection conforms to design intent.
2. Attend commissioning meetings scheduled by the CxA.
3. Provide the following submittals to the CxA:
 - a. Hardware and software submittals
 - b. Control panel construction shop drawings.
 - c. Narrative description of control sequences for each commissioned system and subsystem.
 - d. Schematics showing all control points, sensor locations, point names, actuators, controllers and where necessary, points of access.
 - e. A list of all control points, including analog inputs, analog outputs, digital inputs and digital outputs. Include the values of all parameters for each system point. Provide a separate list for each stand-alone control unit.
 - f. A complete listing of all software routines employed in operating the control system. Also provide a program narrative that describes the logic flow of the software and the functions of each routine and sub-routine. The narrative should also explain individual math or logic operations that are not clear from reading the software listing.
 - g. Hardware operation and maintenance manuals.
 - h. Application software and project applications code manuals.
 - i. Panel and equipment insert documents.
 - j. As-Built control drawings.
4. Verify that specified interfaces provided by others are compatible with BAS hardware and software.
5. Coordinate installation and programming of BAS with construction and commissioning schedules.
6. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
7. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned equipment.
8. Provide control system technician to assist during equipment startup.
9. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
10. Participate in the Functional Performance Tests as required by the project specifications.
11. Provide a control system technician to assist during verification and performance testing.
12. Provide system modifications to achieve system operation as defined by the design intent.
13. Provide support and coordination for TAB contractor. Provide all devices, such as portable operator terminals and all software for the TAB to use in completing TAB procedures.
14. Provide written notification that the TCC scope of work has been completed in accordance with the project specifications, and that the equipment, systems and sub-systems are operating in accordance with design intent, and that BAS is functioning in accordance with design intent.
15. Participate in the Functional Performance Tests as required to achieve design intent.
16. Participate in the off-season mode testing as required to achieve design intent.
17. Participate in O&M Training as required by project specifications. Include training on hardware operations and programming.

G. Elevator Contractor Responsibilities (ELC)

1. Review design for proper provisions for elevator equipment.
 - a. Verify proper hardware specifications exist for performance as defined by the OPR.

- b. Verify proper safeties and interlocks are included in the design of electrical connections for elevator equipment.
 - 2. Attend commissioning meetings scheduled by the CxA.
 - 3. Verify proper installation and performance of all installation services provided.
 - 4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
 - 5. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of elevator equipment.
 - 6. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
 - 7. Provide an elevator system technician to assist during verification and performance testing.
 - 8. Participate in the Functional Performance Tests as required to achieve design intent.
 - 9. Participate in the off-season mode testing as required to achieve design intent.
 - 10. Participate in O&M Training as required by project specifications.
- H. Electrical Systems Responsibilities – EC, EPEC, LCEC, PVC
 - 1. Review design for provision of power to the commissioned equipment.
 - a. Verify proper hardware specifications exist for performance as defined by the OPR.
 - b. Verify proper safeties and interlocks are included in the design of electrical connections for HVAC equipment.
 - c. Lighting Controls.
 - 2. Attend commissioning meetings scheduled by the CxA.
 - 3. Verify proper installation and performance of all electrical services provided.
 - 4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
 - 5. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned equipment.
 - 6. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
 - 7. Provide an electrical system technician to assist during verification and performance testing.
 - 8. Participate in the Functional Performance Tests as required to achieve design intent.
 - 9. Participate in the off-season mode testing as required to achieve design intent.
 - 10. Participate in O&M Training as required by project specifications.
 - 11. Provide a complete set of as-built drawings and O&M manuals for review.
- I. Plumbing Contractor Responsibilities (PC)
 - 1. Include cost for commissioning requirements in the contract price.
 - 2. Review design for provision of power to equipment.
 - a. Verify proper hardware specifications exist for performance as defined by the OPR.
 - b. Verify proper safeties and interlocks are included in the design of electrical connections for plumbing equipment.
 - 3. Attend commissioning meetings scheduled by the CxA.
 - 4. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
 - 5. Verify proper installation and performance of all plumbing installation services provided.
 - 6. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned plumbing equipment.
 - 7. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
 - 8. Provide a plumbing system technician to assist during verification and performance testing.
 - 9. Participate in the Functional Performance Tests as required to achieve design intent.

10. Participate in the off-season mode testing as required to achieve design intent.
11. Participate in O&M Training as required by project specifications.

J. Fire Alarm Contractor Responsibilities (FAC)

1. Include cost for commissioning requirements in the contract price.
2. Review design for provision of power to equipment.
 - a. Verify proper hardware specifications exist for performance as defined by the OPR.
 - b. Verify proper safeties and interlocks are included in the design of electrical connections for plumbing equipment.
3. Attend commissioning meetings scheduled by the CxA.
4. Verify proper installation and performance of fire alarm installation services provided.
5. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
6. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned fire alarm equipment
7. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
8. Provide a fire alarm system technician to assist during verification and performance testing.
9. Participate in the Functional Performance Tests as required to achieve design intent.
10. Participate in the off-season mode testing as required to achieve design intent.
11. Participate in O&M Training as required by project specifications.

K. Security System Contractor Responsibilities (SSC)

1. Include cost for commissioning requirements in the contract price.
2. Review design for provision of power to equipment.
 - a. Verify proper hardware specifications exist for performance as defined by the OPR.
 - b. Verify proper safeties and interlocks are included in the design of electrical connections for plumbing equipment.
3. Attend commissioning meetings scheduled by the CxA.
4. Verify proper installation and performance of security installation services provided.
5. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned.
6. Complete System Verification Checklists and manufacturer's pre-start checklists prior to scheduling startup of commissioned security equipment.
7. Monitor and respond to Resolution Tracking Forms distributed by the CxA in order to expedite corrective actions necessary to achieve design intent.
8. Provide a security system technician to assist during verification and performance testing.
9. Participate in the Functional Performance Tests as required to achieve design intent.
10. Participate in the off-season mode testing as required to achieve design intent.
11. Participate in O&M Training as required by project specifications.

L. Building Envelope Contractors – GLC, VC, SC, SHC, WC, IC, WPC, ABC, RC, FPC, MR's

1. Include commissioning requirements in the building envelope contracts, as well as other subcontracts, to assure full cooperation of all parties in the commissioning process.
2. Assure acceptable representation, with the means and authority to prepare and coordinate execution of the mechanical commissioning program as described in the contract documents.
3. Assure that the CxA shall receive a copy of all construction documents, addenda, change orders and appropriate approved submittals and shop drawings for review and use in development of the commissioning plan.
4. Coordinate inclusion of commissioning activities in the construction schedule.

5. Manage participation of appropriate contractors and vendors according to the contract documents and construction schedule.
6. Furnish instrumentation required for demonstration of Owner's Project Requirements compliance of installed systems equipment and assemblies for systems to be commissioned, excluding building pressurization door blowers and thermography equipment noted in this specification.
7. Issue a statement when work has been completed, and that the final test reports have been submitted for review.
8. Facilitate resolution of deficiencies identified by observation or performance testing.
9. Provide the CxA with detailed manufacturer installation instructions, testing laboratory certifications/reports, and full warranty information, including clearly identified owner responsibilities required to keep the warranty in force for its duration.
10. Provide the CxA with logs of installation materials actually shipped with the exterior wall components and the actual field checkout sheet forms used by the manufacturer or field technicians.
11. Contractors shall assist the owner and design consultants in clarifying installation and operation of commissioned assemblies in areas where construction documents and/or installation, operation and maintenance (IO&M) documents are insufficient to write detailed testing procedures.
12. Provide limited assistance to the CxA in preparing specific performance test procedures.
13. Review test procedures for feasibility, safety, material protection, and economic efficiency.
14. Assemble and implement manufacturer installation and checkout plan procedures for commissioned assemblies. Submit these plans to the owner, designers, and the CxA prior to proceeding with installation of building envelope components.
15. Perform and clearly document completed checkout procedures, providing signed and dated copies to the CxA.
16. Conduct testing before installation of insulation and interior closure of the wall. Address current Architect/Engineer (A/E) punch list items before testing. The exterior sections of the building envelope assemblies shall be completed with discrepancies and problems remedied before testing of the exterior wall system or mock-up assemblies.
17. Exterior Wall Contractors will provide installation supervisors to witness execution of specified tests conducted on the mock-up assemblies to resolve installation issues and establish future installation practices necessary to correct deficiencies observed prior to commencing with installation of the exterior wall systems. Exterior Wall Contractors supervisors will be available and present during agreed upon schedules and for sufficient duration to complete the necessary tests, adjustments, and problem solving.
18. Provide access to scaffolds, man-lifts, or other mechanical conveyances used by the exterior wall contractors to perform their work during specified performance testing. If subcontractor's schedule does not allow use of mechanical conveyances for commissioning activities, General Contractor is to provide necessary equipment for execution of specified commissioning tests.
19. Correct deficiencies discovered by the commissioning process.
20. Prepare Operations & Maintenance (O&M) documents as required by specification and contract documents, including accurate existing conditions.
21. Provide specified training of owner personnel and participate in the off-season mode testing as required to achieve Owner's Project Requirements.
22. Coordinate with product manufacturers to provide the owner with specific requirements for maintaining valid warranty conditions.
23. Prepare a preliminary schedule for exterior wall assemblies testing for use by the CxA, and update the schedule appropriately.
24. Notify General Contractor, Architect, and the CxA when exterior wall assemblies tests are ready to occur with responsible advance notification to allow interested parties to participate.
25. Following with the commissioning authority's guidance, contractor items to be performed prior to and after the building envelope/air barrier testing includes the following as applicable:

- a. Disable any HVAC ERUs, exhaust fans and outside air intake dampers and louvers to prevent air leakage or confirm the emergency shut off switch will disable each outside air systems and then re-enable the HVAC systems after the tests if needed.
- b. Remove one ceiling panel in each office and in large rooms, one ceiling panel per 500 SF of ceiling area and reinstall ceiling panels.
- c. Install and adjust door hardware and weather stripping on the exterior doors so they will latch closed and seal to prevent air leakage.
- d. Install blank covers or seal open electrical and data/communication junction boxes in the air barrier system.
- e. Disable specific door closure arms at the designated exterior doors that the blower door fan system will be installed and reinstall door closure arms after testing.
- f. Confirm each penetration in the building envelope/air barrier has been sealed.
- g. Open and/or install door stops at the conditioned rooms and close the doors to non-conditioned rooms and remove stops after testing.
- h. Confirm each floor drain, mop sink, sink, lavatory, urinal, shower, and/or water closet plumbing trap has water installed to prevent air leakage during testing.
- i. Confirm windows and exterior doors remain closed during the testing and no workmen are mobilizing in and out of the exterior doors during testing.

M. Contractor Commissioning Compliance Issues:

1. Test results that are not within the range of acceptable results are commissioning compliance issues.
2. Track and report commissioning compliance issues until resolution and retesting are successfully completed.
3. If a test demonstration fails, determine the cause of failure. Direct timely resolution of issue and then repeat the demonstration. If a test demonstration must be repeated due to failure caused by Contractor work or materials, reimburse Owner for billed costs for the participation in the repeated demonstration.
4. Test Results: If a test demonstration fails to meet the acceptance criteria, perform the following:
 - a. Complete a commissioning compliance issue report form promptly on discovery of test results that do not comply with acceptance criteria.
 - b. Submit commissioning compliance issue report form to the Commissioning Team.
 - c. Determine the cause of the failure.
 - d. Establish responsibility for corrective action if the failure is due to conditions found to be Contractor's responsibility.
5. Commissioning Compliance Issue Report: Provide a commissioning compliance issue report for each issue. Do not report multiple issues on the same commissioning compliance issue report.
 - a. Exception: If an entire class of devices is determined to exhibit the identical issue, they may be reported on a single commissioning compliance issue report. For example, if all return-air damper actuators that are specified to fail to the open position are found to fail to the closed position, they may be reported on a single commissioning issue report. If a single commissioning issue report is used for multiple commissioning compliance issues, each device shall be identified in the report, and the total number of devices at issue shall be identified.
 - b. Complete and submit the commissioning compliance issue report immediately when the condition is observed.
 - c. Record the commissioning compliance issue report number and describe the deficient condition on the data form.
 - d. Resolve commissioning compliance issues promptly and report resolutions to the Commissioning Team.
6. Diagnose and correct failed test demonstrations as follows:

- a. Perform diagnostic tests and activities required to determine the fundamental cause of issues observed.
 - b. Record each step of the diagnostic procedure prior to performing the procedure. Update written procedure as changes become necessary.
 - c. Record the results of each step of the diagnostic procedure.
 - d. Record the conclusion of the diagnostic procedure on the fundamental cause of the issue.
 - e. Determine and record corrective measures.
 - f. Include diagnosis of fundamental cause of issues in commissioning compliance issue report.
7. Retest:
- a. Schedule and repeat the complete Functional Performance Test procedure for each test demonstration for which acceptable results are not achieved. Obtain signature of Owner's witness on retest data forms. Repeat test demonstration until acceptable results are achieved. Except for issues that are determined to result from design errors or omissions, or other conditions beyond Contractor's responsibility, compensate Owner for direct costs incurred as the result of repeated test demonstrations to achieve acceptable results.
8. Do not correct commissioning compliance issues during test demonstrations.
- a. Exceptions will be allowed if the cause of the issue is obvious and resolution can be completed in a mutually agreed upon brief timeframe by the Commissioning Team. If corrections are made under this exception, note the deficient conditions on the test data form and issue a commissioning compliance issue report.

3.14 APPENDICES

Appendix A – System Verification Checklists Samples

Appendix B – Functional Performance Tests Samples

Appendix C – Air Leakage Test Form

Appendix D – Air Leakage Test Results Form

Appendix E – Test Agency Qualifications Sheet (Pressure Test Agency and Thermographer)

END OF SECTION 019113