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**USACE / NAVFAC / AFCEC / NASA** **UFGS-01 91 19 (May 2023)**

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**Preparing Activity: USACE** **Superseding**
**UFGS-07 05 23 (August 2019)**

**UNIFIED FACILITIES GUIDE SPECIFICATIONS**

**References are in agreement with UMRL dated April 2023**
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**********

SECTION 01 91 19

BUILDING ENCLOSURE COMMISSIONING
**05/23**

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**NOTE: This guide specification covers building enclosure/envelope commissioning, including requirements for pressure testing a building's air barrier for air leaks. Minimizing air leakage through an air barrier helps reduce energy costs. This specification is applicable to new building construction and major renovations involving upgrades to the building envelope.**

**Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

**Remove information and requirements not required in respective project, whether or not brackets are present.**

**Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR).**

**NOTE: TO DOWNLOAD UFGS GRAPHICS AND APPENDICES Go to**
http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/for
**********

PART 1 GENERAL

**********

**NOTE: This UFGS Section contains tailoring options for Contractor (KTR) HIRED COMMISSIONING PROVIDER, GOVT HIRED COMMISSIONING PROVIDER, DESIGN-BUILD, ARMY, and NAVY.**

Select KTR HIRED COMMISSIONING PROVIDER tailoring for projects that require the Commissioning Provider to be provided by the Construction Contractor.

Select GOVT HIRED COMMISSIONING PROVIDER tailoring for projects where the Commissioning Provider is retained under a separate Contract with the Government.

Select DESIGN-BUILD tailoring for Design-Build project execution.

Select ARMY tailoring for projects that will report the real property asset for Air Force or Army.

Select NAVY tailoring for projects that will report the real property asset for Navy or Marine Corps.

Verification of the energy performance of the building envelope is required for all projects that require commissioning and verification in accordance with UFC 1-200-02; facilities that require air barrier inspection and testing are defined within UFC 3-101-01. As directed in UFC 1-200-02, the Commissioning requirements in this Section are based on ASHRAE 90.1 as required for commercial and multi-family high-rise buildings; for projects involving low-rise residential buildings this Section will need to be edited to meet the Commissioning requirements of IECC. For commissioning requirements of Medical Treatment Facilities, refer to UFC 4-510-01 and edit this Section accordingly. When a project requires this Section, edit and include UFGS Section 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM for additional performance testing and verification requirements. For projects where more oversight is needed beyond the minimum building envelope requirements of ASHRAE 90.1 and the requirements of Section 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM, revise this specification accordingly. (Examples include facilities with pressurization or humidity control requirements such as armories, electronic equipment facilities, hospitals, and laboratories.)

Coordinate this Section with the commissioning requirements of ASHRAE 90.1, as required by UFC 1-200-02, "High Performance and Sustainable Building Requirements" paragraph "Commissioning."

**********

**********

NOTE: The basis for the air leakage testing within this specification is UFC 3-101-01 and the U.S. Army Corps of Engineers Air Leakage Test Protocol for Measuring Air Leakage in Buildings. This protocol can be found at the following web site: https://www.wbdg.org/FFC/ARMYCOE/usace_airleakagetestprotocol.pdf.

**This specification includes additional recommendations not found in the aforementioned protocol. These recommendations are based on personal pressure test experience and discussions with industry experts.**

**An Excel spreadsheet titled Pressure Test Data Analysis, available for download at http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/for is an integral part of the building's air barrier pressure test. Data obtained during the test may be input into the spreadsheet to determine the air barrier's leakage rate.**

**This specification describes the responsibilities of the Contractor and the Contractor's pressure test agency. The building designer is responsible for creating, defining and detailing the air barrier envelope. The Contractor's pressure test agency is responsible for preparing the building envelope for the pressure test, performing the test, recording test results, and returning the building to pre-test conditions. The test agency is also responsible for performing the calculations to determine if the envelope passed the pressure test. Diagnostic testing is also the responsibility of the test agency.**

**This specification does not cover duct and HVAC system pressure testing and is limited to the envelope penetrating dampers as deemed applicable for leakage testing. Duct and HVAC system pressure testing references can be obtained from ASHRAE Handbook of Fundamentals, HVAC Design Section and Chapters and ASHRAE Standard 215, Method of Test to Determine Leakage of Operation HVAC Air Distribution Systems, should duct and HVAC system pressure testing be required by other specifications. See Section 23 05 93, TESTING, ADJUSTING, AND BALANCING FOR HVAC for duct testing requirements.**

**********

## 1.1 SUMMARY

Use this Section in conjunction with UFGS 01 91 00.15 BUILDING COMMISSIONING. Building Enclosure Commissioning (BECx) is an essential part of overall Building Commissioning. The final BECx report is part of the Final Commissioning Report as defined in 01 91 00.15 BUILDING COMMISSIONING. This Section covers Building Enclosure Commissioning for all six surfaces (4 walls, roof, and floor, for a rectangular shaped zone) of a building. Additional Quality Control and testing requirements for specific components of the building enclosure are described in the Division 03 thru 08 UFGS Sections of the project specifications.

## 1.2 REFERENCES

**********

**NOTE: This paragraph is used to list the publications cited in the text of the guide**

**specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.**

**Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.**

**References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.**

**********

The publications listed below form a part of this specification to the extent referenced. The publications are referenced within the text by the basic designation only.

AMERICAN ARCHITECTURAL MANUFACTURERS ASSOCIATION (AAMA)

| | |
|---|---|
| AAMA 501.2 | (2015) Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls and Sloped Glazing Systems |

AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING (ASNT)

| | |
|---|---|
| ANSI/ASNT CP-105 | (2020) ASNT Standard Topical Outlines for Qualification of Nondestructive Testing Personnel |
| ANSI/ASNT CP-189 | (2020) ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel |
| ASNT SNT-TC-1A | (2020) Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing |

AMERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS (ASHRAE)

| | |
|---|---|
| ASHRAE 90.1 - IP | WARNING: Text in tags exceeds the maximum length of 300 characters |
| ASHRAE 202 | (2018) Commissioning Process for Buildings and Systems |
| ASHRAE RP-935 | (1998) Protocol for Field Testing of Tall Buildings to Determine Envelope Air Leakage Rate |

ASTM INTERNATIONAL (ASTM)

| | |
|---|---|
| ASTM C1193 | (2013) Standard Guide for Use of Joint |

| | |
|---|---|
| | Sealants |
| ASTM D3464 | (1996; R 2014) Standard Test Method for Average Velocity in a Duct Using a Thermal Anemometer |
| ASTM D4541 | (2017) Standard Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers |
| ASTM E779 | (2019) Standard Test Method for Determining Air Leakage Rate by Fan Pressurization |
| ASTM E783 | (2002; R 2018) Standard Test Method for Field Measurement of Air Leakage Through Installed Exterior Windows and Doors |
| ASTM E1105 | (2015; R 2023) Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls, by Uniform or Cyclic Static Air Pressure Difference |
| ASTM E1186 | (2022) Standard Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems |
| ASTM E1258 | (1988; R 2018) Standard Test Method for Airflow Calibration of Fan Pressurization Devices |
| ASTM E1827 | (2022) Standard Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door |
| ASTM E2029 | (2011) Standard Test Method for Volumetric and Mass Flow Rate Measurement in a Duct Using Tracer Gas Dilution |
| ASTM E2813 | (2018) Standard Practice for Building Enclosure Commissioning |
| ASTM E2947 | (2021) Standard Guide for Building Enclosure Commissioning |

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

| | |
|---|---|
| ISO 6781 | (1983) Thermal Insulation - Qualitative Detection of Thermal Irregularities in Building Envelopes - Infrared Method |
| ISO 6781-2 | (2010) Performance of Buildings - Detection of Heat, Air, and Moisture Irregularities in Buildings by Infrared Methods - Part2: Equipment Requirements |
| ISO 6781-3 | (2015) Performance of Buildings - Detection of Heat, Air, and Moisture |

Irregularities in Buildings by Infrared Methods - Part 3: Qualifications of Equipment Operators, Data Analysts, and Report Writers

## 1.3 DEFINITIONS

The definitions included here are specific to this Section. Refer to UFGS 01 91 00.15 BUILDING COMMISSIONING for definitions that apply to both Sections. The following terms as they apply to this section:

### 1.3.1 Air Barrier Envelope

The surface that separates the inside air from the outside air. The combination of air barrier assemblies and air barrier components, connected by air barrier accessories are designed to provide a continuous barrier to the movement of air through an environmental separator. A single building may have more than one air barrier envelope. The air barrier surface includes the top, bottom, and sides of the envelope. The term "air barrier envelope" is also known as "air barrier system" or simply "air barrier".

### 1.3.2 Air Leakage Rate

A measurement of air infiltration or exfiltration through the building envelope over time. The air leakage rate is the rate of air flow across the air barrier per unit surface area of the envelope at a defined differential pressure.

### 1.3.3 Basis of Design (BoD)

A document developed by the design team which includes technical concepts, assumptions, calculations, decisions, and product selections to support the Owner's Project Requirements (OPR).

### 1.3.4 Bias Pressure

Also known as zero flow pressure, baseline pressure, offset pressure or background pressure. With the envelope not artificially pressurized, bias is the differential pressure that always exists between the envelope that has been prepared (sealed) for the pressure test and the outdoors. Bias pressure is made up of two components, fixed static offset (usually due to stack effect or the HVAC system) and fluctuating pressure (usually due to wind or a moving elevator). Because of pressure fluctuations many bias pressure readings are recorded and averaged for use in the calculations.

### 1.3.5 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 air flow 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.

1.3.6 Building Enclosure (or envelope)

The materials, components, systems, and assemblies intended to provide an environmental separator between the interior and exterior or between interior spaces with different environment requirements. "Enclosure" is used interchangeably with "envelope".

1.3.7 Building Enclosure Commissioning (BECx)

Technical service provided on behalf of the Government to provide a quality-focused process for enhancing the performance of the building enclosure by validating the design phase and verifying during the construction phase that the performance of the building enclosure materials components, assemblies, and systems are designed and installed to meet the Owner's Project Requirements (OPR).

1.3.8 Building Enclosure Commissioning Provider (BECxP)

An entity that functions as part of the overall Commissioning Team and is responsible for validating the design phase and verifying during the construction phase that the performance of the building enclosure materials, components, assemblies, and systems are designed and installed to meet the Owner's Project Requirements (OPR).

1.3.9 Construction Phase

The period of a project following the award of construction Contract to project completion.

1.3.10 Design Phase

The period of the project delivery process when a design supporting the Owner's Project Requirements is developed and translated into Contract Documents.

1.3.11 Environmental Separator

The parts of a building that separate the controlled interior environment from the uncontrolled exterior environment, or that separate spaces within a building that have dissimilar environments. The term "environmental separator" is also known as the "control layer".

1.3.12 Functional Performance Test (FPT)

A systematic process to verify that controls and other elements of the building project are capable of and configured to operate or perform as required.

[1.3.13 Owner's Project Requirements (OPR)

**********

**NOTE: The Owner's Project Requirements (OPR) document may be included as deemed appropriate by the project team or as required by some Third Party Certification (TPC) systems (such as LEED and Green Globes). The preliminary design deliverables and preliminary design authority (PDA) documentation (such as 1391, Basis of Design, and UFCs) constitute the Owner's Project Requirements (OPR) and may be**

**used in lieu of a stand-alone OPR. If used, the OPR is referenced by the CxC during design review when the specification is tailored for KTR HIRED COMMISSIONING PROVIDER.**

**NOTE: The Owner's Project Requirements (OPR) document may be included as deemed appropriate by the project team or as required by some Third Party Certification (TPC) systems (such as LEED and Green Globes). When not otherwise required for TPC, inclusion of the OPR for CxC review may be beneficial for ensuring large or complex projects conform to the Owner's needs. This may be unnecessary for more typical construction projects. If used, the OPR is referenced by the CxC during design review and during submittal review, inspections, and testing.**

**NOTE: If used, insert the OPR as Appendix A to Section 01 91 00.15 BUILDING COMMISSIONING. Include a statement on the OPR cover stating that the document is provided for commissioning review purposes only and is not a Contract requirement. Retain the bracketed references to Owner's Project Requirements (OPR) throughout the specification when one is included. Delete the bracketed OPR references when the OPR is not included.**

**********

A document that details the stakeholders' requirements for the project and the expectations for how it will be used and operated. The OPR is provided for commissioning review purposes only and is not a Contract requirement.

]1.3.14 Pressure Test

A generic term for a test in which the envelope is either pressurized or de-pressurized with respect to the outdoors.

1.3.15 Negative Pressure Test (Depressurization Test)

A test wherein air inside the envelope is drawn to the outdoors. This places the envelope at a lower (negative) pressure with respect to the outdoors.

1.3.16 Positive Pressure Test (Pressurization Test)

A test wherein outdoor air is pushed into the envelope. This air movement places the envelope at a higher (positive) pressure with respect to the outdoors.

1.3.17 Verification & Testing (V&T) Provider

An entity who completes the activities needed to implement the building functional performance testing (FPT) activities or verify that elements of the building project meet stated requirements.

1.4 COMMUNICATION WITH THE GOVERNMENT COMMISSIONING PROVIDER

For communication responsibilities, see Section 01 91 00.15 BUILDING COMMISSIONING.

1.5 COMMUNICATION WITH GOVERNMENT ACCCEPTANCE TESTING REPRESENTATIVES

**********
**NOTE: The following paragraph is tailored for use on NAVY projects only.**
**********

The QC Manager must communicate directly with the Government Acceptance Testing Representatives and Contracting Officer's Representative regarding Government acceptance testing activities. Inform the Contracting Officer's Representative when systems are ready for testing to be witnessed by Government Acceptance Testing Representatives, and allow access to the construction site and system(s) to be tested

1.6 ENCLOSURE COMPONENTS TO BE COMMISSIONED

**********
**NOTE: The following components are required to be commissioned per ASHRAE 90.1. Select all systems that are part of the scope. Add other systems as required by the scope of the project or required by the applied sustainable third-party certification program.**

**Whole building air tightness testing is required for all projects as outlined in the Editor's Note for the Part 3 section BUILDING ENVELOPE AIR TIGHTNESS REQUIREMENT; however, this test is performed near the end of the project. Once the building enclosure is fully constructed, installation corrections needed to comply with the test requirements may require substantial disassembly and re-work. Smaller scale tests performed on mock-ups or at the initial installation of building components are recommended to validate the design and installation of building enclosure elements and systems. These tests may include:**

**Adhesion tests on liquid-applied or adhered waterproofing and air/weather barrier such as ASTM D4541, Test Method for Pull-off Strength Coatings Using Portable Adhesion Testers.**
**Air leakage testing of fenestration or opaque walls using a site-built test chamber to provide different pressures such as ASTM E783, Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors.**
**Small scale tests of waterproofing or air weather barriers such as the bubble test described in ASTM E1186, Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.**
**Water penetration tests of fenestration with a site-built test chamber (same chamber as ASTM E783) per ASTM E1105, Test Method for Field Determination**

**of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference.**

**Water penetration testing using a hose with a calibrated nozzle such as AAMA 501.2, Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtainwall, and Sloped Glazing Systems.**

**Adhesion and cohesion testing of sealants according to ASTM C1193, Guide for Use of Joint Sealants: Field-Applied Sealant Joint Hand Pull Tab.**

**Depending on the project complexity, budget, and interior environmental requirements, consider including the small-scale testing listed above on mock-ups or early in the installation of that construction component. Additional tests not listed may be selected in consultation with the BECxP and Design Team. See ASTM E2813 for additional test options. Select and include additional building enclosure tests required to verify envelope performance as appropriate to the project complexity, OPR, environmental requirements and geographic location.**

**********

1.6.1 Verification of the Design and Installation of the Continuous Air Barrier

a. Conduct periodic field inspection of the continuous air barrier materials and assemblies, including all penetrations through the six sides of the air barrier, during construction while the continuous air barrier is still accessible for inspection and repair (after installation of all penetrations and wall cladding anchoring devices and before the installation of interior finishes) to verify and document compliance with the requirements. Conduct inspections at initial installation of each building envelope component and at in-progress construction intervals as stated in Part 3 section titled BUILDING ENVELOPE INSPECTION AND TESTING.

[ b. Conduct Performance Verification Testing of the entire building envelope (systems, components, and assemblies) for air tightness in accordance with Part 3 section titled BUILDING ENVELOPE AIR TIGHTNESS REQUIREMENT.]

1.6.2 Inspection of Fenestration and Doors

a. Fenestration and Doors must be labeled and inspected to verify compliance with Building Envelope energy requirements, including applicable U-factors, Solar Heat Gain Coefficient (SHGC), Visible Transmittance (VT), and air leakage rates.

b. Inspect doors and windows for coordination with the insulating plane of the wall, continuity with the air/weather barrier, and flashing.

c. Inspect operation of doors, closers, and operating mechanisms for conformance with manufacturer's instructions.

d. Inspect seals and gaskets for fenestration and doors (including

loading dock, sectional, and coiling doors) for proper installation and to verify that seals are in good condition.

1.6.3 Inspection of Opaque Roof, Walls, and Floors

Opaque roof, above-grade and below-grade walls, and floors, must be subject to the following inspections during construction:

a. Use of ASHRAE 90.1 - IP-compliant materials and assemblies.

b. Insulation material meets design specifications and is continuous.

1.6.4 Fenestration Inspections

Conduct inspections of the following fenestration-related items during construction:

a. Skylights size and location in relation to the designed primary sidelighted area and secondary sidelighted area below.

b. Roof monitor size and location in relation to the designed primary sidelighted area and secondary sidelighted area below.

c. Dynamic glazing compliance with SHGC and U-factors, and testing of the operation for conformance with the manufacturer's instructions.

d. Permanent fenestration projections installation and performance in accordance with ASHRAE 90.1 - IP requirements and the Contract documents.

[1.6.5 Loading Dock Weatherseal Inspections

**********
**NOTE: Include this paragraph where loading dock weatherseals are a part of the project.**
**********

Inspect loading dock weatherseals for proper installation and to verify the seals are in good condition.

][1.6.6 Additional Building Enclosure Tests

**********
**NOTE: Include any additional testing needed to verify performance of the building enclosure elements in this paragraph, with examples in the prior Editor's Note.**
**********

Conduct the following building enclosure tests on mock-ups or early in the installation of the related building components:

[ ]

]1.7 SUBMITTALS

**********
**NOTE: Review submittal description (SD) definitions**

**in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.**

**For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.**

**The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third-Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.**

**Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.**

**********

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Building Enclosure Commissioning Specialist Qualifications; G [, [_____]]

Building Enclosure Testing Work Plan; G [, [_____]]

SD-03 Product Data

Thermal Imaging Camera; G[, [_____]]

Test Equipment; G[, [_____]]

SD-05 Design Data

Envelope Surface Area Calculations; G[, [_____]]

SD-06 Test Reports

Completed Building Envelope Inspection Checklists; G[, [_____]]

Pressure Test Procedures; G[, [_____]]

Air Leakage Test Report; G[, [_____]]

Diagnostic Test Report; G[, [_____]]

SD-07 Certificates

Pressure Test Agency

Thermographer Qualifications

Certificate of Readiness

SD-10 Operation and Maintenance Data

Training; G[, [_____]]

## 1.8 BUILDING ENCLOSURE TESTING WORK PLAN

For each building enclosure test to be performed, submit the following not later than [120] [_____] calendar days [after Contract award, but] before start of testing work, steps to be taken by the lead test technician to accomplish the required testing.

a. Memorandum of test procedure.

(1) Proposed dates for conducting the tests.

(2) Submit detailed test procedures prior to the test. Provide a plan view showing proposed locations (personnel doors or other similar openings) to install equipment (such as blower doors or flexible ducts for trailer-mounted fans, if used).

b. Test equipment to be used.

c. Scaffolding, scissor lifts, power, electrical extension cords, duct tape, plastic sheeting and other Contractor's support equipment required to perform all tests.

d. Other Contractor's support personnel who will be on site for testing.

## 1.9 ACCESSIBILITY REQUIREMENTS

Air barrier components, insulation, fenestration, and doors for commissioned systems must be made accessible for inspections. Contractor must make necessary modifications at Contractor's own expense if systems and enclosures are not accessible for inspections and testing. Assist commissioning team in testing and inspections by removing equipment covers, opening access panels, and other required activities that assist with visual oversight. Furnish ladders, flashlights, meters, gauges, or other inspection equipment as necessary.

## 1.10 SCHEDULING

**********
**NOTE: The following paragraph is tailored for NAVY. For Navy projects, roof systems are considered critical systems per NAVFACINST 3960.1. Quality Assurance functions by NAVFAC is done on the roofing systems to ensure Contractor's construction quality control (CQC) program and commissioning deliver a high quality and properly functioning critical system.**
**********

Notify the Contracting Officer a minimum [14][ ] calendar days in advance of site visits and inspections by the roof system manufacturer technical representative for coordination with the Government Acceptance Testing Representative.

## 1.11 COORDINATION

Refer to Section 01 91 00.15 BUILDING COMMISSIONING for requirements pertaining to coordination during the commissioning process. Coordinate with the Commissioning Provider in accordance with Section 01 91 00.15 BUILDING COMMISSIONING and in accordance with the Commissioning Plan to schedule inspections as required to support the commissioning process. Furnish additional information requested by the Commissioning Provider.

Coordinate scheduling of air barrier inspections and air barrier pressure testing with the commissioning team. Upload plans, reports, notes, and other documentation to the Commissioning Provider's web-based commissioning software, or as specified in the commissioning plan, as it is completed.

## 1.12 QUALITY CONTROL

### 1.12.1 Modification of References

Perform all pressure and diagnostic tests according to the referenced publications listed in paragraph REFERENCES and as modified by this section. Consider the advisory or recommended provisions, of the referred references, as mandatory.

### 1.12.2 Qualifications

#### 1.12.2.1 Building Enclosure Commissioning Specialist Qualifications

See UFGS 01 91 00.15 BUILDING COMMISSIONING for the qualification requirements of the Building Enclosure Commissioning Specialist.

#### 1.12.2.2 Pressure Test Agency

Submit, no later than [15] [_____] calendar days after Contract award, information certifying that the pressure test agency is not affiliated with any other company participating in work on this Contract. The work of the test agency is limited to pressure testing the building envelope, performing a thermography test and fog test, and investigating, through various methods, the location of air leaks through the air barrier. See Part 3 paragraph PRESSURE TEST AGENCY for additional requirements. For

thermographer qualifications, see paragraph THERMOGRAPHER QUALIFICATIONS.

Use the sample TEST AGENCY QUALIFICATIONS SHEET form (Appendix C), to submit the following information.

a. Verification of [2][_____] years of experience as an agency in pressure testing commercial or industrial buildings.

b. List of at least ten commercial/industrial facilities with building envelopes that the agency has tested within the past 2 years. Include building name, address, and name of prime construction Contractor and Contractor's point-of-contact information.

c. Confirmation of 2 years of commercial and or industrial building pressure test experience for the lead pressure test technician and the thermographer in using the specified ASTM E779 or ASTM E1827 testing standard. References from five Contracting Officers for facilities where the lead test technician has supervised commercial and or industrial building pressure tests in the last 2 years.

d. Verification that the lead pressure test technician has been employed by a building pressure testing agency in the capacity of a lead pressure test technician for not less than 1 year.

1.12.2.3 Thermographer Qualifications

To perform an infrared diagnostic evaluation, use a lead thermographer who has at least an active Level II Certification that is based on the requirements in ANSI/ASNT CP-105 or ANSI/ASNT CP-189 and is in accordance with ASNT SNT-TC-1A. The course of study is to be specifically focused on infrared thermography for building science. 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. Thermographic equipment operators, data analysts and report writers must comply with the requirements of ISO 6781-3. Submit the thermographer's certificate for approval. Submit a list of at least ten commercial/industrial buildings on which the thermographer has performed IR thermography in the past two years. The thermographer is to have a current active certification. Submit certification at least 60 days prior to thermography testing.

1.12.3 Test Reports

No later than 14 days after completion of the pressure test, submit electronic copies of an organized report[ and [_____] bound paper copies in a durable 3-ring binder]. The report is to contain a table of contents, an executive summary, an introduction, a results section and a discussion of the results. Submit the air leakage test report as described in paragraph AIR LEAKAGE TEST REPORT. Submit a diagnostic test report as described in paragraph LOCATING LEAKS BY DIAGNOSTIC TESTING. The diagnostic test report is to include the Thermographic Investigation Report and the Fog Test Report (if performed).

Submit field data and completed report forms found in the appendices. Use the sample forms, Test Agency Qualification Sheet, Air Leakage Test Form and Air Leakage Test Results Form to summarize the tests for the appropriate building envelope. Submit both electronically populated and

field hand filled-in forms.

Report Data. Include in the report the following information for all tests:

a. Date of issue

b. Project title and number

c. Name, address, and telephone number of testing agency

d. Dates and locations of samples and tests or inspections

e. Names of individuals making the inspection or test

f. Designation of the work and test method

g. Identification of product and specification section

h. Complete inspection or test data

i. Test results and an interpretation of test results

j. Comments or professional opinion on whether inspected or tested work complies with Contract document requirements

k. Recommendations on retesting

## 1.13 CLIMATE CONDITIONS SUITABLE FOR A PRESSURE TEST

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. Based on current and forecast weather conditions, the Contracting Officer's representative is to grant final approval for testing to occur.

### 1.13.1 Rain

**********
**NOTE: Leakage through some floor, roof, and wall assemblies can be affected by heavy rain when minute cracks and holes become temporarily sealed. Rain may close potential leaks, making the envelope appear tighter than it would be in drier conditions. Rainwater can also block pneumatic tubes used in pressure testing thereby altering differential pressure readings.**
**********

For safety reasons, avoid testing during rain or if rain is anticipated during testing. If pneumatic hoses are installed and exposed to rain inspect the hose to ensure 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.

1.13.2 Wind

Because wind can skew pressure test results, test only on days and at times when winds are anticipated to be the calmest. Avoid pressure testing during gusty or high wind conditions. Avoid installing test fans on the windward side of the building if wind gusts during the test are anticipated to be greater than 16.1 kilometers/hour 10 miles per hour.

1.14 CERTIFICATE OF READINESS

**********
**NOTE: This paragraph contains tailoring options for ARMY and NAVY. Select or insert the number of calendar days for desired notification prior to system commissioning tests. Include the last bracketed sentence when the project requires air tightness testing; whole building envelope air tightness testing is required for projects as outlined in the Editor's Note for the Part 3 section BUILDING ENVELOPE AIR TIGHTNESS REQUIREMENT.**
**********

Prior to scheduling the Commissioning Tests as required by this Section, submit Certificate of Readiness documentation in accordance with Section 01 91 00.15 BUILDING COMMISSIONING for each enclosure-related system, certifying that inspections have been completed, open issues have been resolved, and the system is ready for the Commissioning Tests. Documentation would include Building Envelope Inspection Checklists as required within this Section, as well as any inspections or test reports required within each enclosure-related technical specification section. Additional Quality Control and testing requirements for specific components of the building enclosure are described in the Division 03 thru 08 UFGS Sections of the project specifications.

Submit the Certificate of Readiness for each system [30][____] calendar days [20][____] working days prior to Commissioning Tests of that system. Do not schedule Commissioning Tests for a system until the Certificate of Readiness is approved by the Government. [Do not schedule air tightness testing of the building envelope system until Certificates of Readiness and supporting documentation for enclosure-related systems have been submitted, reviewed and approved by the Government.]

PART 2 PRODUCTS

2.1 TEST EQUIPMENT

Provide all equipment required to perform testing for the systems and components to be commissioned. Provide all testing equipment of sufficient quality and accuracy to test and measure system performance with the tolerances specified. Provide a sufficient quantity of two-way radios for each subcontractor.

Submit a signed and dated list of instruments to be used for testing, their application, manufacture, model, serial number, range of operation accuracy, and date of most recent calibration. Calibration data applicable to fan systems must be in accordance with ASTM E1258. Also list special equipment and proprietary tools specific to a piece of equipment required for testing.

## 2.2 PRESSURE TEST EQUIPMENT

**********
**NOTE: The size of the envelope and the abundance of leaks through the envelope determines the type and quantity of pressure testing equipment needed. A single blower door system usually provides sufficient airflow (2360 to 3775 L/s5000 to 8000 CFM ) to test an average single family residence. A building the size of a basketball gymnasium may require two or more blower door systems. Logistically there may be an upper limit to the number of blower door systems that can be installed and operated together. The author of this specification has anecdotal knowledge of up to 24 blowers being used in one test to deliver about 90,615 L/s 192,000 CFM at 75 Pa. This means that a building envelope of up to about 71,350 sq. m 768,000 sq. ft can be pressure tested to meet a leakage rate of 1.27 L per sec/sq. m. 0.25 cfm/sq. ft. at 75 Pa using blower door equipment. Trailer mounted fans that can typically deliver up to 28,317 L/s 60,000 CFM may be used for both pressurization and de-pressurization. Blower door systems and trailer mounted fans may also be used together in a test. If blower door systems and trailer mounted fans provide insufficient air for pressure testing, the building's own air handling system can be used in lieu of blower door fans and trailer mounted fans. Obtaining accurate flow reading when using a building's own air handling system may be especially challenging. Delete unnecessary pressure test methods as necessary.**
**********

Depending on site conditions and size of the envelope, the test may be conducted using [blower door equipment] [and] [trailer-mounted fans] [or the building's own supply air system]. 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.

### 2.2.1 Blower Door Fans and Trailer Mounted Fans

**********
**NOTE: For General Information Only. There currently are only 3 manufacturers of blower door equipment in the United States. Infiltec, Minneapolis Blower Door and Retrotec. The author has anecdotal knowledge of blower door and trailer-mounted fan testing being used in Canada, Great Britain, Ireland, Australia and some Scandinavian countries.**
**********

Each air flow measuring system including blower door fans and trailer mounted fans are to be calibrated within the last 5 years. Calibrated

blower door fans and trailer mounted 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.

2.2.2 Digital Gages as Test Instruments

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.

2.3 THERMAL IMAGING CAMERA REQUIREMENTS

The thermal imaging camera used in the thermography test must have a thermal sensitivity (Noise Equivalent Temperature Difference.) of +/- 0.1 degree C at 30 degrees C 0.18 degrees F at 86 degrees F or less. Ensure the camera's operating spectral range falls between 2 and 15 micrometers. Ensure the camera's IR image viewing screen resolution measures at least 320x240 pixels. Ensure the camera has 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. All thermographic equipment must comply with the requirements of ISO 6781-2. Submit camera make and model, and catalog information that defines the camera thermal sensitivity for approval.

PART 3 EXECUTION

**********

**NOTE: Select and include in Part 1 of this Section and later in Part 3 those building enclosure tests required to verify envelope performance as appropriate to the project complexity, OPR, environmental requirements and geographic location. Tests should be selected through consultation between the BECxP and Design Team. ASTM E2813 provides a list of options for building enclosure tests that might be included. Note that all testing listed in ASTM E2813 is not required; thus, the text below states to follow ASTM E2947 except where it references ASTM E2813.**

**********

Conduct building enclosure commissioning in accordance with ASHRAE 202 and ASTM E2947 in addition to the requirements herein. Follow ASTM E2947 except where it references ASTM E2813. Commissioning must document in sufficient detail compliance of the building envelope with the design intent as defined in the Contract documents.

3.1 MEETINGS

Attend all meetings in accordance with Section 01 91 00.15 BUILDING COMMISSIONING.

Provide timely updates on construction schedule changes so Commissioning Provider has scheduling information needed to execute commissioning process efficiently. Notify Contracting Officer of anticipated construction delays to commissioning activities not yet performed or not yet scheduled.

## 3.2 DESIGN PHASE COORDINATION MEETING

**********

**NOTE: This Article is tailored for inclusion in DESIGN-BUILD projects only. This Article also includes tailoring for ARMY and NAVY. Select which design submittal will include the design phase commissioning coordination meeting. Also, select or insert which Government representatives need to be invited to the meeting.**

**********

Participate in a design phase commissioning coordination meeting led by the CxC prior to the [35] [50] percent design submittal for systems to be commissioned. The purpose of the meeting is to discuss the commissioning process, including project Contract requirements, lines of communication, roles and responsibilities, schedules, documentation requirements, and to develop a Preliminary BECx Plan.

The Quality Control team, Designer of Record, and the Government Acceptance Testing Representatives and other Government team members must attend this meeting. Invite the User and[ a Directorate of Public Works Representative][ a Reserve Support Command Representative][ ][ a Public Works Division Representative][ ] to attend this meeting. Meeting may be conducted by teleconferencing.

## 3.3 PRELIMINARY BECx PLAN

**********

**NOTE: The Article contains tailoring options for DESIGN-BUILD and DESIGN-BID-BUILD projects.**

**********

Submit the Preliminary BECx Plan no later than 14 calendar days after the Design Commissioning Coordination Commissioning Kickoff Meeting. Submit the Preliminary BECx Plan for inclusion in the Design Phase Interim Construction Phase Commissioning Plan as identified in Section 01 91 00.15 BUILDING COMMISSIONING. Coordinate the development of this plan with the commissioning plans required in Section 01 91 00.15 BUILDING COMMISSIONING. Outline the commissioning process, commissioning team members and responsibilities, lines of communication, inspections, and documentation requirements for BECx. Identify the Commissioning Standards chosen for the project. Establish appropriate and quantifiable enclosure related performance metrics, test standards, and test methodology in accordance with referenced standards for inclusion in the Contract documents. Provide a list of team members for systems to be commissioned with contact information, a list of tests as required to complete the scope of all commissioning and a copy of the project schedule as required by Section 01 32 17.00 20 COST-LOADED NETWORK ANALYSIS SCHEDULE 01 32 01.00 10 PROJECT SCHEDULE for inclusion in the Preliminary BECx Plan.

The Preliminary BECx Plan must include, at a minimum, the following:

1. Required performance of commissioned equipment, systems, and assemblies, and results of FPT and verification.

2. Summary of compliance of the building and its components, assemblies, controls, and systems with requirements.

3. Issues and resolution logs, including itemization of deficiencies found during verification, testing, and commissioning that have not been corrected at the time of report preparation.

4. Deferred tests that cannot be performed at the time of report preparation.

5. Documentation of the training of operation personnel and building occupants on commissioned systems, and a plan for the completion of any deferred trainings not completed at the time of report preparation.

6. A plan for the completion of commissioning and training, including climatic and other conditions required for performance of the deferred tests.

[3.4 DESIGN REVIEW

**********

**NOTE: For Navy, the Design Review is a bracketed selection; select the Design Review paragraph if a design review is required after contract award. For Army tailoring, the paragraph is not bracketed. The commissioning design review report is required for Army managed projects and may be required by applicable Sustainability third Party Certification guidelines. This Article contains tailoring options for ARMY, NAVY, KTR HIRED COMMISSIONING PROVIDER and GOVERNMENT HIRED COMMISSIONING PROVIDER. Choose bracketed language regarding the Owner's Project Requirements Document for projects that require one (refer to specifier note regarding OPR in paragraph DEFINITIONS for further information). Select the design submittal on which the design review will occur; depending on the size and complexity of the project, review of multiple design submittals can be included.**

**NOTE: When a KTR hired commissioning provider is used for a DESIGN-BID-BUILD project, the first opportunity for the BECxP to review the project is early in construction. Leveraging the BECxP's experience in review of the design to identify any remaining problems allows early correction, where correction is necessary. This can allow major problems to be addressed with minimal time and cost growth during construction. The Government, in coordination with designers, must review the Design Review Report to determine if any design changes are necessary. Changes to the construction contract are still at the sole discretion of the Contracting Officer.**

**********

The BECxP must review enclosure-related design documents. The review must occur prior to the [50 percent][PRE-FINAL][FINAL] design submittal. The design review must include verifying that the design for the systems to be commissioned are prepared in accordance with the Contract documents

Provide a Design Review Report identifying discrepancies or deficiencies that would prevent the systems to be commissioned from operating or performing in accordance with the design requirements or being safely maintained. Submit the building enclosure-related Design Review Report for inclusion in the overall project Design Review Report as identified in Section 01 91 00.15 BUILDING COMMISSIONING. Report must include individual list of each deficiency and corresponding corrective action necessary for proper system performance. [Identify any discrepancies between the design and the Owner's Project Requirements Document. The Owner's Project Requirements Document is provided for commissioning review purposes only and does not form a part of the contract documents for this project.] Submit the Design Review Report no later than [14][__] calendar days after approval of the Commissioning Firm and Commissioning Specialists after completing the review of the design. The Contracting Officer, Construction Manager, the Contractor's Project Manager, the BECxP, and the Designers of Record for the associated systems must meet, discuss, and resolve any outstanding items contained in the report no later than 14 calendar days after submission of the report. The BECxP must verify that their review comments have been adequately addressed in subsequent design submittals.

The BECxP is responsible for reviewing the design and preparing a Design Review Report identifying discrepancies or deficiencies that would prevent the systems to be commissioned from operating or performing in accordance with the design requirements or being safely maintained. The Contracting Officer, the CxC, the BECxP, and the Designers of Record for the associated systems must meet, discuss, and resolve any outstanding items contained in the report no later than 14 calendar days after submission of the report. The BECxP must verify that the review comments have been adequately addressed in subsequent design submittals.

Give particular attention to the continuity of the air barrier, vapor and moisture control within enclosure assembly, acoustic control of the enclosure assemblies to meet required Outdoor Indoor Transmission Class (OITC) values, flashing, thermal bridges, and resistance to water penetration or ponding.

]3.5 FINAL BECx PLAN

**********
**NOTE: This Article includes tailoring for ARMY and NAVY projects.**
**********

Submit the Final BECx Plan for inclusion in the Interim Construction Phase Commissioning Plan as identified in Section 01 91 00.15 BUILDING COMMISSIONING. Outline the commissioning process, commissioning team members and responsibilities, lines of communication, and documentation requirements for BECx. Identify the Commissioning Standards chosen for the project. Identify enclosure related inspections, performance metrics, test standards, and test methodologies in accordance with referenced standards for inclusion in the commissioning process.

Provide a list of team members for systems to be commissioned with contact information, a list of tests as required by this Section as well as 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM, and a copy of the project schedule as required by Section 01 32 17.00 20 COST-LOADED NETWORK ANALYSIS SCHEDULE 01 32 01.00 10 PROJECT SCHEDULE for inclusion in the Final BECx Plan. Final BECx plan must be submitted with the Interim Construction Phase Commissioning Plan, and must be updated and included with the Final Construction Phase Commissioning Plan as identified in Section 01 91 00.15 BUILDING COMMISSIONING.

## 3.6 CONSTRUCTION SUBMITTAL REVIEWS

**********
**NOTE: This Article contains tailoring options for KTR HIRED COMMISSIONING PROVIDER, GOVT HIRED COMMISSIONING PROVIDER, and DESIGN BUILD.**
**********

Coordinate construction submittal document reviews for commissioned systems and assemblies with the CxC and BECxP. The commissioning submittal review does not replace the designer of record (DoR) or Government submittal review, in accordance with Section 01 33 00 SUBMITTAL PROCEDURES.

The BECxP must identify construction submittals to be provided by the Contractor for the commissioned systems, and coordinate with the CxC. The BECxP must evaluate construction submittals related to BECx for compliance with the Contract documents. The BECxP is responsible for identifying construction submittals to be provided by the Contractor for the commissioned systems and coordinating with the CxC. The BECxP is responsible for evaluating construction submittals related to BECx for compliance with the Contract documents. The DoR must consider the BECxP's comments and provide direction to the Contractor as necessary. Provide a copy of final DoR submittal reviews with comment responses to the BECxP. Include a copy of the submittal document review transmittal and response in the Commissioning Report.

## 3.7 TEMPLATE BUILDING ENVELOPE INSPECTION CHECKLISTS

**********
**NOTE: This Article contains tailoring options for KTR HIRED COMMISSIONING PROVIDER, and GOVT HIRED COMMISSIONING PROVIDER.**
**********

The Building Enclosure Commissioning Specialist must develop the Template Building Envelope Inspection Checklists to verify the building materials and construction maintain the required air tightness of the building envelope system.

Use the Template Building Envelope Inspection Checklists prepared by the CxC to verify the building materials and construction maintain the required air tightness of the building envelope system.

The Building Envelope Compliance Documentation Form from ASHRAE 90.1 - IP User's Manual may be used as an example. The submitted checklist is not required to match the format of the form; however, the checklist must contain the same level of detail as shown on the mandatory provisions of the sample form.

## 3.8 BUILDING ENVELOPE INSPECTION AND TESTING

**********

**NOTE: This Article contains tailoring options for KTR HIRED COMMISSIONING PROVIDER and GOVT HIRED COMMISSIONING PROVIDER.**

**Edit the frequency of site visits based on the size and complexity of the project. Monthly inspections at a minimum are recommended as air barrier construction progresses; also take into account the complexity of the project (such as lab or medical facility vs. a storage building). Keep in mind it is best to inspect during initial construction installation of key envelope elements; subpar conditions are difficult to correct in later stages of construction.**

**Whole building envelope air tightness testing is required for projects as outlined in the Editor's Note for the Part 3 section BUILDING ENVELOPE AIR TIGHTNESS REQUIREMENT; include the last bracketed sentence when the project requires air tightness testing.**

**********

Demonstrate that all system components have been installed, that each building enclosure component operates, and that the systems operate and perform in accordance with Contract documents and the Owner's Project Requirements. Provide all materials, services, and labor required to perform the Building Envelope Inspections.

Document building envelope inspections by the commissioning team using the approved Template Building Envelope Inspection Checklists. Indicate commissioning team member inspection and validation of each Building Envelope Inspection Checklist item by initials at the time they are inspected and found to be in conformance with Contract requirements. Inspect checklist items before they become hidden as construction progresses. Submit the initialed and completed Building Envelope Inspection Checklists no later than 14 calendar days after completion of inspection of all checklist items. The BECxP must conduct inspections at initial installation of each building envelope component and a minimum of [monthly][_____] site visits to the site to observe construction of the building envelope in-progress, each time reviewing the in-progress checklists to ensure that the commissioning team is inspecting the building envelope as required. Coordinate inspection requirements with Section 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM and other Division 7 Specifications. [The BECxP must witness the building envelope pressure tests and diagnostic tests specified in this Section; review the resulting reports; and provide recommendations for correction of any deficiencies or further testing.]

Participate in periodic building envelope inspections with the commissioning specialists using the approved Template Building Envelope Inspection Checklists to observe and document construction of the building envelope in-progress. Coordinate inspection requirements with Section 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM and other Division 7 Specifications. Complete the checklists and indicate inspection and

validation of each Building Envelope Inspection Checklist item by initials at the time they are inspected. Notify the Commissioning Specialist and Contracting Officer at least 21 calendar days before checklist items are concealed to ensure inspection items can be observed before construction progresses. Submit the initialed and Completed Building Envelope Inspection Checklists no later than 14 calendar days after completion of inspection of all checklist items. [Notify the BECx at least 21 calendar days prior to the building envelope pressure tests and diagnostic tests specified in this Section.]

[3.8.1 Additional Building Enclosure Testing

**********

**NOTE: Select and include those building enclosure tests required to verify envelope performance as appropriate to the project complexity, OPR, environmental requirements and geographic location. Tests should be selected through consultation between the BECxP and Design Team. ASTM E2813 provides a list of options for building enclosure tests that might be included. Some options include:**

**Adhesion tests on liquid-applied or adhered waterproofing and air/weather barrier such as ASTM D4541, Test Method for Pull-off Strength Coatings Using Portable Adhesion Testers.**

**Air leakage testing of fenestration or opaque walls using a site-built test chamber to provide different pressures such as ASTM E783, Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors.**

**Small scale tests of waterproofing or air weather barriers such as the bubble test described in ASTM E1186, Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems.**

**Water penetration tests of fenestration with a site-built test chamber (same chamber as ASTM E783) per ASTM E1105, Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference.**

**Water penetration testing using a hose with a calibrated nozzle such as AAMA 501.2, Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtainwall, and Sloped Glazing Systems.**

**Adhesion and cohesion testing of sealants according to ASTM C1193, Guide for Use of Joint Sealants: Field-Applied Sealant Joint Hand Pull Tab.**

**********

[ a. Conduct adhesion tests on liquid-applied and adhered waterproofing and air/weather barrier in accordance with ASTM D4541.

][b. Conduct air leakage testing of fenestration in accordance with ASTM E783.

][c. Conduct small scale bubble tests of waterproofing and air/weather

barriers in accordance with ASTM E1186.

][d. Conduct water penetration tests of fenestration in accordance with ASTM E1105.

][e. Conduct water penetration tests of installed storefronts, curtainwall, and sloped glazing systems in accordance with AAMA 501.2.

][f. Conduct adhesion and cohesion tests of sealants in accordance with ASTM C1193.

][g. [_____]

]]3.9 BUILDING ENCLOSURE AIR BARRIER PRESSURE TESTING

3.9.1 Pressure Test Agency

Employ an independent agency to conduct the pressure test on the building envelope in accordance with ASTM E779 and this specification section. The test agency is to be an independent third-party subcontractor, not an affiliated or subsidiary of the prime Contractor, subcontractors, or A/E firm. The agency is to be regularly engaged in pressure testing of commercial/industrial building envelopes. If using blower door or trailer-mounted fans, 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. Technicians using the building's air handling system for pressure testing are to have tested at least five commercial/industrial buildings within the past two years with each building having over 4645 square meters 50,000 square feet of floor area. Submit the name, address, and floor areas of each of these five buildings for approval.

3.9.1.1 Field Work

The lead pressure test technician and thermographer are to be present at the project site while testing is performed and is to be responsible for conducting, supervising, and managing of their respective test work. Management includes health and safety of test agency employees.

3.9.1.2 Reporting Work

The lead pressure test technician is to prepare, sign, and date the test agenda, equipment list, and submit a certified Air Leakage Test Report. The thermographer is to prepare, sign, and date the test agenda, equipment list, and submit a certified Thermographic Investigation Report. The Contractor is to prepare a final report that identifies improvements that were made to the envelope to reduce air leaks [, mitigate thermal bridging][, eliminate moisture migration,][, repair insulation voids] discovered during diagnostic tests. The Verification & Testing (V&T) providers must certify completion of required verification and FPT and include a plan for the completion of any deferred FPT, including climatic and other conditions required for performance of the deferred tests; include the results of the FPT and verification activities in the completed verification and FPT (functional performance testing) documentation. Jointly submit all reports.

3.9.2 Envelope Surface Area Calculation

**********

**NOTE: The design architect is responsible for defining the air barrier boundary (all 6 sides), showing the boundaries on the drawings, calculating the air barrier envelope surface area, and showing the calculation result on the drawings.**

**********

The architectural air barrier boundary includes the floor, walls, and ceiling. After construction of the air barrier envelope is complete, field measure the envelope to ensure the physical measurements match the design drawings and the air barrier envelope surface area calculations are generated. If the calculation result is not within 10 percent of the defined air barrier boundary calculation result as indicated, submit the envelope surface area calculation and results for review. [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.]

3.9.3 Preparing The Building Envelope For The Pressure Test

3.9.3.1 Testing During Construction

The pressure test cannot be conducted until all components of the air barrier system have been installed. After all sealing as described herein has been completed, inspect 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. Recommend testing prior to installing the finished ceilings and interior wall finishes within the envelope and immediately surrounding it. The absence of finishes allows for inspection 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.

3.9.3.2 Sealing the Air Barrier Envelope

**********

**NOTE: The design drawings are to detail architectural treatments necessary to provide a complete air barrier including sealing all interfaces in the air barrier envelope.**

**********

The Contractor is to seal all penetrations through the air barrier. Unavoidable penetrations due to electrical boxes or conduit, plumbing, and other assemblies that are not air-tight 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 to withstand the maximum positive and negative air pressure to be placed on the building without displacement or damage, and transfer the load to the structure. 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. Do not install

lighting fixtures that are equipped with ventilation holes through the air barrier.

3.9.3.3 Sealing Plumbing

Prime all plumbing traps located within the envelope full of water.

3.9.3.4 Close and Lock Doors

Close and lock all doors and windows in the envelope perimeter. For doors not equipped with latching hardware, temporarily secure them in the closed position. Secure the doors in such a way that they remain fully closed even when the maximum anticipated differential air pressure produced during the test acts on them. Provide signage stating not to open the door and the time and duration of the test.

3.9.3.5 Hold Excluded Building Areas at the Outdoor Pressure Level

Keep building areas immediately surrounding but excluded from the test envelope at the outdoor pressure level during the pressure test. Maintain these areas at the outdoor pressure level by propping exterior doors open, opening windows and de-energizing all air moving devices in or serving these areas.

3.9.3.6 Maintain an Even Pressure within the Envelope

Ensure the pressure differences within the envelope are minimized by opening all internal air pathways including propping open all interior doors. Distribute test fans throughout the envelope as necessary to ensure the internal pressures are uniform (within 10 percent of the average differential pressure). Ideally, do not install suspended ceilings until after all pressure tests have been completed. If, however the envelope includes finished suspended ceiling spaces, temporarily remove approximately 5 percent of all ceiling tiles or a minimum of 1 tile from each isolated suspended ceiling space, whichever comprises the greatest surface area. Temporarily remove additional ceiling tiles during testing to allow for inspection and diagnostic testing of the ceiling/wall interface. An alternative to removing ceiling tiles is to measure the differential pressure between each isolated suspended ceiling space and the outdoors when the area below the suspended ceiling is maintained at a differential pressure of 75 Pa with respect to the outdoors. If the suspended ceiling differential pressure measurement is within ten percent of the 75 Pa pressure below the suspended ceiling no ceiling tiles need to be removed.

3.9.3.7 Maintain Access to Mechanical and Electrical Rooms

Maintain access to mechanical rooms and electrical rooms associated with the envelope to allow for de-energizing ventilation equipment and resetting circuit breakers tripped by blower door equipment, if used.

3.9.3.8 Minimize Potential for Blowing Dust and Debris

Because high velocity air will be blown into and out of the envelope during the test, debris, including dust and litter, may become airborne. Airborne debris may become trapped or entangled in test equipment, thereby skewing test results. Ensure areas within and surrounding the envelope are 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.

3.9.3.9 De-energize Air Moving Devices

De-energize all air moving devices serving the envelope to keep air within the envelope as still as reasonably achievable. De-energize all fans that deliver air to, exhaust air from, or recirculate air within the envelope. Also, de-energize all fans serving areas adjacent to but excluded from the envelope.

[3.9.3.10 Installing Blower Door Equipment in a Door Opening

**********
**NOTE: Delete this paragraph if blower door equipment will not be used for the pressure test.**
**********

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 1.5 m 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-fan pressure. Avoid installing blower door equipment on the windward side of the building.

]3.9.4 Building Envelope Air Tightness Requirement

**********
**NOTE: UFC 3-101-01 imposes air tightness requirements for all buildings but requires only inspection (and not air tightness leak testing) for the specific building types. See UFC 3-101-01 for building types which require only inspections.**

**Seal existing buildings undergoing major renovations, especially the ones located in cold or hot and humid climates, to the same standard as newly constructed ones. The air barrier boundaries of the conditioned portion may not necessarily follow the exterior boundary of the building; it may only be a part of the whole. For additional guidance, see Air Leakage Test Protocol for Building Envelope at the following site: (https://www.wbdg.org/FFC/ARMYCOE/usace_airleakagetestprotocol.pdf).**

**The Architectural Plus HVAC test should be applied in the specifications of a Contract when the building is designed such that the HVAC system may operate intermittently and when dampers will be utilized to prevent air leakage out of the conditioned space through the HVAC system. The Architectural Plus HVAC test may be applied to residential projects with intermittent HVAC system operation or a project in which there is a need to verify mechanical dampers in the HVAC system for leakage performance.**
**********

For each building envelope, perform the Architectural Only test and if

noted below, the Architectural Plus HVAC System test. 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). The tests may be performed in any desired order.

3.9.4.1 Architectural Only Test

The test envelope is the architectural air barrier boundary as defined on the Contract drawings. This boundary includes connecting walls, roof and floor 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.

3.9.4.1.1 Test Goal

**********

**NOTE: Edit and include Section 07 27 10.00 10, BUILDING AIR BARRIER SYSTEM. The paragraph of Section 07 27 10.00 10 titled "Air Barrier Envelope Surface Area and Leakage Requirements" includes the allowable leakage rate. These rates are different depending on if the test is Architectural Only or Architectural Plus HVAC System.**

**********

Input data from the test into the Air Leakage Rate by Fan Pressurization spreadsheet as described in paragraph CALCULATION PROGRAM via the Air Leakage Test Form. Compare output from the spreadsheet against the maximum allowable leakage defined in Section 07 27 10.00 10 BUILDING AIR BARRIER SYSTEM. The envelope passes the test if the leakage rate, as calculated using the spreadsheet, is equal to or lower than the Architectural Only leakage rate goal.

3.9.4.1.2 Preparing the Envelope for the Pressure Test - Seal All Openings through the Air Barrier

Temporarily close all perimeter windows, roof hatches and doors in the envelope perimeter except for those doors that are to remain open to accommodate blower door or trailer mounted fan test equipment installation. Seal, or isolate all other intentional openings, pathways, and fenestrations through the architectural envelope prior to pressure testing. Follow the Recommended Test Envelope Conditions identified in ASTM E1827, Table 1, for the Closed Envelope condition. These openings may include boiler flues, fuel-burning water heater flues, fuel-burning kitchen equipment, clothes dryer vents, fireplaces, wall or ceiling grilles, diffusers, and other similar openings. Before sealing flues, close their associated fuel valves and verify the associated pilot lights are extinguished. Prime all plumbing traps located within the envelope full of water. In lieu of applying tape or plastic, typical temporary sealing materials include tape and sheet plastic or a self-adhesive grille wrap. Use and apply tape and plastic in a manner that does not deface or remove paint or mar the finish of permanent surfaces. Be especially aware of residue that remains from tape applied to stainless steel surfaces such as kitchen hoods or rollup doors. For painted surfaces, use tape types that do not remove finish paint when the tape is removed. If paint is removed from the finished surface, repaint to match existing surfaces. Secure dampers closed either manually or by using the building's HVAC

system controls. Use the table below for further guidance in building preparation.

| Building Component | Envelope Condition |
|---|---|
| Air handling units, duct fans | As found (open) or temporarily sealed as necessary |
| Clothes dryer | Off |
| Clothes dryer vents | Temporarily sealed |
| Dampers - intake, exhaust | Physically closed or closed using control power or temporarily sealed |
| Diffusers, registers, grilles within the envelope | Temporarily sealed |
| Doors, personnel type, at the envelope perimeter | Secured closed |
| Doors, personnel type, within the envelope | Secured (propped) open |
| Doors, roll-up type, at the envelope perimeter | Closed (no additional sealing) |
| Exhaust hoods | Closed* and temporarily sealed |
| Fireplace hearth | Temporarily sealed * |
| Kitchen hoods | Temporarily sealed * |
| Pilot light and associated fuel valve | Extinguished and closed, respectively |
| Vented combustion appliance | Temporarily sealed * |
| Vented combustion appliance exhaust flue | Off |
| Windows | Secured closed |
| * If the building component has an associated manual or automatic damper, consider securing the damper closed in lieu of temporarily sealing. | |

[3.9.4.2 Architectural Plus HVAC System Test

**********

**NOTE: The Architectural Plus HVAC System test should be applied in the specifications of a Contract when the building is designed such that the HVAC system may operate intermittently and when dampers will be used to prevent air leakage out of the conditioned space through the HVAC system. The Architectural Plus HVAC System test may be applied to residential projects with intermittent HVAC system operation or a project in which there is a need to verify mechanical dampers in the HVAC system for leakage performance. Include or remove this paragraph as required.**

**********

This test envelope includes the architectural air barrier boundary as defined on the Contract 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.

3.9.4.2.1 Test Goal

**********

**NOTE: Edit and include Section 07 27 10.00 10, BUILDING AIR BARRIER SYSTEM. The paragraph of Section 07 27 10.00 10 titled "Air Barrier Envelope Surface Area and Leakage Requirements" includes the allowable leakage rate. These rates are different depending on if the test is Architectural Only or Architectural Plus HVAC System.**

**********

Data from the test is to be input into the Air Leakage Rate by Fan Pressurization spreadsheet as described in paragraph CALCULATION PROGRAM via the Air Leakage Test Form. If both positive and negative pressure tests were performed, both data sets are to be input in the spreadsheet. Compare output from the spreadsheet against the leakage rate goal. The envelope passes the test if the leakage rate, as calculated using the spreadsheet, is equal to or lower than the Architectural Plus HVAC System leakage rate goal.

3.9.4.2.2 Preparing the Building for the Pressure Test

In preparation for this test, de-energize all air moving devices within this envelope by putting their controls in the Unoccupied mode. This allows the building's HVAC controls to close all associated motorized intake, exhaust, and relief dampers. Make no other changes to the HVAC systems. Temporarily sealing diffusers, grilles, registers, kitchen hoods, exhaust hoods, fans, air handling units and all other HVAC system elements with tape or plastic sheeting or any other means is not allowed. If the envelope includes a fireplace hearth do not seal it with tape and plastic. Use the table below for further guidance in building preparation.

| Building Component | Envelope Condition |
|---|---|
| Air handling units, duct fans | As found (open) |
| Clothes dryer | Off |
| Clothes dryer vents | As found (no preparation) |
| Dampers - intake, exhaust | As found (no preparation) |

| Building Component | Envelope Condition |
|---|---|
| Diffusers, registers, grilles within the envelope | As found (open) |
| Doors, personnel type, at the envelope perimeter | Secured closed |
| Doors, personnel type, within the envelope | Secured (propped) open |
| Doors, roll-up type, at the envelope perimeter | Closed (no preparation) |
| Exhaust hoods | Closed |
| Fireplace hearth | As found (open) |
| Kitchen hoods | As found (open) |
| Pilot light and associated fuel valve | Extinguished and closed, respectively |
| Vented combustion appliance | Off |
| Vented combustion appliance exhaust flue | As found (open) |
| Windows | Secured closed |

]3.9.5 Conducting The Pressure Test

Notify the Contracting Officer at least ten(10) working days before conducting the pressure tests to provide the Government the opportunity to witness the tests and to monitor weather forecasts for conditions favorable for testing. Do not pressure test until verifying that the continuous air barrier is in place and installed without failures in accordance with installation instructions. During the pressure test periodically inspect temporarily sealed items to ensure they are still sealed. Seals on temporarily sealed items tend to release more readily at higher pressures. Test data obtained after temporarily sealed items become unsealed cannot be used as input into the calculation program. Follow the Envelope Pressure Test Procedures in the paragraphs below. Submit detailed pressure test procedures indicating the test apparatus, the test methods and procedures, and the analysis methods to be employed for the building envelope pressure (air tightness) test. Submit these procedures not later than 60 days after Notice to Proceed.

3.9.5.1 Extend Pneumatic Tubes and Establish a Reference Differential Pressure

Confirm the various zones within the envelope have a relatively uniform interior pressure distribution by establishing a representative differential pressure between the envelope and the outdoors with blower door or trailer-mounted fans operating. The number of indoor pressure difference measurements (pneumatic hoses) required depends on the number of interior zones separated by bottle necks that could create significant pressure drops (e.g., doorways and stairwells). Extend at least four pneumatic hoses (differential pressure monitoring ports) to locations within the envelope that are physically opposite of each other. In multiple story buildings, especially those over three stories, extend

hoses to multiple floors. Locate the hose ends away from the effects of air discharge from blower test equipment. Select one of the four (or more) interior hoses, one judged by the test agency to be the most unaffected by air velocity produced by blower test equipment, to serve as the interior reference pressure port. Extend at least one additional pneumatic hose to the outdoors (outdoor pressure port). To the end of this hose manifold at least four hoses together and terminate each hose on a different side of the building. With the envelope sealed and the blowers energized, measure the differential pressure using the interior reference pressure port and the four outdoor pressure ports. Then measure and record the differential pressure by individually using each of the remaining three interior hoses. Ensure each reading is within plus or minus 10 percent of the reference reading. Thus, at an average 75 Pa maximum pressure difference across the envelope, the difference between the highest and lowest interior pressure difference measurements should be 15 Pa or less. If this condition cannot be met, attempt to create additional air pathways within the envelope to minimize pressure differences within the envelope. If necessary, move the interior hose ends. See step 2.13 of the Air Leakage Test Form in Appendix A.

3.9.5.2 Bias Pressure Readings

With the fan pressurization equipment de-energized and the envelope sealed, obtain the differential pressure between the outdoors and the envelope. Record 12 bias pressure readings before the pressure test and 12 bias pressure readings after the pressure test. Each reading is the average of ten or more 1-second measurements. Include positive and negative signs for each reading. To help dampen bias pressures that significantly contribute to test pressure, reduce temperature differences between indoor and outdoor air. Temperature differences can be reduced by operating test fan equipment for a few minutes to replace most of the indoor air with outdoor air.

3.9.5.3 Testing in Both Positive and Negative Directions

**********

**NOTE: The preferred way to dampen bias pressure due to wind is to test the building envelope in both the pressurization and depressurization directions and average the results. Bias pressures are nonlinear and cannot be adequately allowed for by merely subtracting the bias from the pressure reading. Testing in both directions more effectively dampens bias pressures thus tolerating the occurrence of larger bias pressures during a test, up to 30 percent of the lowest test pressure. Allow single direction testing only if testing in both directions cannot logistically be performed.**

**********

The preferred method for testing a building envelope is to test in both the pressurized and depressurized directions. Testing in one direction is only allowed if opposite direction testing cannot logistically be performed due to test equipment limitations or restrictions. After obtaining the pre-test bias differential pressure readings, conduct the pressure test. Record the envelope pressures (in units of Pascals) from one interior pneumatic hose (monitoring port) and the outdoor pneumatic hose(s), averaged or manifolded, with corresponding flows (in units of L/s cfm) for each fan. Record the flow rates at least 10 to 12 positive and

10 to 12 negative building pressure readings. If conducting both positive and negative pressure tests the lowest allowable test pressure is 40 Pa and the highest test pressure is 85 Pa. Keep at least 25 Pa difference between the lowest and highest test pressure readings. Include the 75 Pa pressure value between the lowest and highest readings. The 10 to 12 readings in each direction are to be roughly evenly spaced along the range of pressures and flows. After testing is complete de-energize the equipment used to provide pressurization and obtain an additional 10 to 12 post-test bias pressure readings. None of the bias pressure readings are allowed to exceed 30 percent of the minimum test pressure. If these limits are exceeded the test fails and must be repeated.

[3.9.5.4 Single Direction Testing

**********

**NOTE: Allowing testing in only one direction, acknowledges that very large buildings may require truck or trailer mounted blower equipment that logistically will not easily allow testing in both positive and negative directions. Because bias pressures will have a greater impact on single-direction tests, the maximum allowable bias pressure under these circumstances is 10 percent of the lowest test pressure. At these generally higher pressures, the effects due to bias pressure is somewhat masked by the higher test pressure range. Because building envelopes are often leakier when measured in one direction than the other, testing in only one direction is considered less accurate than testing in both directions. Assume for example, that the bias pressure in a 12 m40 foot high building envelope where the temperature is -18 degrees C 0 degrees F outside and 20 degrees C 68 degrees F inside and with negligible wind is 10.5 Pa. This bias pressure can typically be assumed to be 5.25 Pa at the top of the building envelope and -5.25 Pa at the bottom of the building envelope.**

**********

After obtaining the 12 aforementioned bias pressure readings, conduct the [positive][negative] pressure test. Obtain flow rates at 10 to 12 roughly evenly spaced pressure readings over a pressure range of 50 to 85 Pa. After the data is recorded, de-energize the blower equipment and obtain an additional 10 to 12 bias pressure readings. None of the bias pressure readings may exceed 10 percent of the minimum test pressure. If these limits are exceeded the test fails.

]3.9.5.5 Using a Building's Own Air Handling System to Pressure Test an Envelope

**********

**NOTE: Very few US standards exist that adequately address the special requirements for pressurizing an envelope using the building's own air handling system. However, ASTM E779 attempts to address this topic. Canadian General Standards Board reference CAN/CGSB-149.15, "Determination of the Overall Envelope Airtightness of Buildings by Fan Pressurization Method Using the Building's Air**

**Handling Systems" may help the designer better understand this test method. Using the building's air handling system is a less preferred test method due to the difficulty obtaining accurate readings and should only be used if a door blower fan is not feasible.**

**********

3.9.5.5.1 Test Setup

Temporarily seal the envelope in a manner similar to that for testing with blower door or trailer-mounted fans. To positively pressurize the envelope, de-energize all ventilation equipment and close all associated dampers, except those outside air intake dampers associated with supply fans that will be used to pressurize the building envelope. Fully open these dampers. For the negative pressure test, de-energize all ventilation equipment except for those fans that will be used to de-pressurize the envelope. All dampers associated with de-energized fans are to be closed and all exhaust dampers associated with fans used to de-pressurize the envelope will be fully opened.

3.9.5.5.2 Measuring Airflows

When using the building's own air handling system to pressure test the envelope, air flows can generally be measured using one of the following methods:

a. [When testing using the building's own air handling system, ensure flow readings obtained by anemometer comply with ASTM D3464. ]Pitot tube or hot wire anemometer traverse in accordance with ASTM D3464.

b. Pressure compensated shrouds (especially recommended for rooftop exhaust fans)

c. Tracer gas methods for measuring airflows in ducts in accordance with ASTM E2029. Do not use tracer gas decay, constant injection, and constant concentration methods for estimating the total ventilation rate of the envelope.

3.9.5.5.3 Outdoor Air Flow Measuring Stations

Air flow stations may be used to measure outdoor airflows if one of the above methods is used to check accuracy of at least one air flow reading for each station or if the design of the HVAC system specifically placed outdoor air flow stations in locations that will yield accurate results. Field verify the accuracy of readings at the air flow measuring stations before obtaining pressure test readings.

3.9.5.6 Pressure Testing - Special Cases

[3.9.5.6.1 Pressure Testing a Tall or Large Building Envelope

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**NOTE: Use this method only if the entire envelope cannot be pressure tested using the methods previously described. Note that if this method of pressure testing is used, the Architectural Plus HVAC test cannot be performed.**

**********

Pressure testing the envelope of a tall or large building may be unworkable and unrealistic using blower door or trailer-mounted equipment. In this case, the test agency may define and pressure test separate zones or floors within the envelope and sum the leakage all of the zones to create an overall envelope leakage rate. Using this method, the test agency is to comply with the requirements of ASHRAE RP-935.

]3.9.5.6.2 Pressure Testing a Multiple Isolated Zoned Building

**********

**NOTE: Some buildings may consist of multiple zones that do not share a common air plenum and cannot easily be modified to do so. Typically, these buildings are dormitories, apartment buildings, hotels and offices wherein occupants enter and leave each zone via a separate, exclusive, exterior door. Walls and floors isolate each zone such that no discernable air pathway between zones exists. In this case, testing cannot be performed on the entire building envelope; rather, several representative air barrier zones within the building are to be individually pressure tested.**

**********

Pressure test each exterior corner zone plus at least an additional 20 percent (as measured by floor area) of remaining zones. The Contracting Officer is responsible for selecting which of these additional zones to test. If all zones pass the pressure test it is assumed that all untested zones also pass and no further testing is required. If, however, any zone fails to pass the test's leakage requirements, re-seal, and re-test until it passes in accordance with paragraph FAILED PRESSURE TEST. Test an additional 20 percent of previously untested zones. If all tested zones pass, no further testing is needed. If any zone in this group fails the test re-seal and re-test the zone until it passes. Continue this process until all the tested zones pass. When testing a zone, the doors to all adjacent zones that share a common surface with the tested zone are to have their doors opened to the outdoors. The resulting leakage from the test zoned is that through all six surfaces (4 walls, roof, and floor, for a rectangular shaped zone).

3.9.5.6.3 Pressure Testing a Building Addition

**********

**NOTE: UFC 3-101-01 indicates that pressure testing a new building addition is not required if the interface between new and existing surfaces cannot be (or are not) adequately sealed for testing. An accurate pressure test can still be performed on the building addition using the method described in this paragraph. If a pressure test is performed on the addition, the surface area calculation should only include those surfaces equipped with an air barrier and not the interface (common) surfaces.**

**********

If the existing building is occupied, coordinate the pressure test with building representatives. In preparation of the test, de-energize the air handling system serving that portion of the existing building that shares

surfaces with the new building addition. Pressure testing a new building addition may also require pressurizing that part of the existing building that shares surfaces in common with the new building addition. If an air barrier is applied to the common surfaces separating the existing building from the new addition, prior to the test prop open a sufficient quantity of doors and windows to keep the existing building at the same pressure as the outdoors. If an air barrier is not applied to the common surfaces separating the existing building from the new addition, pressurize that part of the existing building that shares surfaces in common with the building addition to the same level as the as the addition using separate test pressurization equipment.

3.9.5.7 Failed Pressure Test

If the pressure test fails to meet the established criteria, use diagnostic test methods described in paragraph LOCATING LEAKS BY DIAGNOSTIC TESTING to discover the leak locations. Provide additional permanent sealing measures to reduce or eliminate leak sources discovered during diagnostic testing. Retest (perform another pressure test) after sealing has been completed. Repeat this sequence of documenting test results in the test report, performing diagnostic tests, documenting recommendations for additional sealing measures in the test report, sealing leak locations per recommendations, and re-testing as necessary until the building envelope passes the pressure test and is in compliance with the performance requirements.

3.9.5.8 Air Leakage Test Report

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**NOTE: Edit and include Section 07 27 10.00 10, BUILDING AIR BARRIER SYSTEM. The paragraph of Section 07 27 10.00 10 titled "Air Barrier Envelope Surface Area and Leakage Requirements" includes the allowable leakage rate. These rates are different depending on if the test is Architectural Only or Architectural Plus HVAC System.**

**********

Report volumetric flow rates and corresponding differential pressures in liters per second (L/s) cubic feet per minute (cfm) and Pascals (Pa), respectively, on the Air Leakage Test Form sample form found in Appendix A. Populate the accompanying spreadsheet file titled Pressure Test Data Analysis with information obtained during the test. The spreadsheet uses equations found in ASTM E779 as a basis for calculating the envelope leakage rate. Other similar leakage rate calculation programs cannot be used or submitted for review. Submit a printout of the data input and output in the report. Should any air tightness (pressure) test fail, the pressure test report is to include data and results from all previous failed tests along with the final successful test data and results. Indicate if the resulting leakage rate did or did not meet the goal leakage requirement. Identify and document deficiencies in the building construction upon failure of a test to meet the specified maximum leakage rate.

Test reports on leakage tests performed using fan pressurization must meet ASTM E779 requirements; reports on tests performed utilizing blower door testing must meet ASTM E1827 requirements. Include the Test Agency Qualification Sheet, Air Leakage Test Form and Air Leakage Test Results Form in the written report. Document every test set-up condition with

diagrams and photos to ensure the tests can be made repeatable. Document all pneumatic hose termination locations. Record in detail how the building envelope was prepared for the tests. Also describe in detail which building items were temporarily sealed. Include photos of test equipment and sealing measures in the report. Include an electronic (pdf) version of all test reports on a CD. If the building envelope fails to meet the leakage rate goal, provide recommendations to further seal the envelope and document these recommendations in the test report.

### 3.9.6 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. Apply additional diagnostic tests (find, feel, fog or other tests) as necessary to further define leak locations and pathways discovered using thermography or to find additional leaks not readily detected by thermography. 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 (such as ducts, pipes, and conduit) 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.

#### 3.9.6.1 Sealing and Re-Testing

Should leaks be discovered during diagnostic tests, thoroughly document the exact leak locations on a floor plan so that sealing can be later applied, if required or as directed. 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 COR based on the magnitude, location, potential for liquid moisture penetration or retention, potential 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. 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.

#### 3.9.6.2 Find Test

Use visual observation to locate daylight or artificial light streaming from the opposite side of the envelope. Observe all interfaces identified above.

#### 3.9.6.3 Feel Test

Use the building's air handling system or blower door equipment to

negatively pressurize the building envelope, to at least 25 Pa but no greater than 85 Pa, with respect to the outdoors. The larger the pressure difference, the easier discovering leaks by feeling them becomes. While inside the envelope, hand feel roof/wall, wall/wall, and floor/wall interfaces and utility penetrations (such as ducts, pipes and conduit) for leaks and note the leak locations on a floor plan. The "Feel" test may also be used to check for leaks between the ductwork and ductwork damper. To do this, positively pressurize the envelope and check for air movement from the envelope exterior.

3.9.6.4 Infrared Thermography Test

**********

**NOTE: Generally, thermography can only be performed if there is a sufficiently significant temperature difference, a minimum of 5 degrees C 9 degrees F per ASTM E1186 between the indoors and outdoors. Pressurizing and depressurizing the envelope while performing thermography can help exaggerate leaks, thereby making them more noticeable.**

**********

Coordinate thermography examination with the pressure test agency and the test agency's pressurization equipment. 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 and exterior, including readings of the roof.

3.9.6.4.1 Thermography Test Methods

Before thermographic testing, remove furniture, construction equipment, and all other obstructions both inside and outside the building as necessary to gain a clear field of view. In the Thermographic Investigation Report, document all areas where obstructions remain. For exterior thermal examination of the envelope, including readings of the roof, verify that no direct solar radiation has heated the envelope surfaces to be examined for a period of approximately 3 hours for frame construction and for approximately 8 hours for masonry veneer construction. Conduct exterior investigations after sunset, before sunrise, or on an overcast day when the influence of solar radiation can be determined to be minimal. Limit exterior examinations to times when the influence of solar radiation is minimal, such as after sunset or before sunrise or during an overcast day. Conduct thermal imaging tests only when wind speeds are less than 8 mph at the time of analysis and at the end of analysis. Document any variations in wind during the test. Document all variations of test conditions in the Thermographic Investigation Report. Test only when exterior surfaces are dry. Monitor and document ongoing test parameters, such as the temperatures inside and outside the air barrier envelope, wind speed, and differential pressure.

3.9.6.4.1.1 Thermography Testing of the Air Barrier

Test the building envelope in accordance with ISO 6781, and ASTM E1186. Perform a complete thermographic inspection consisting of the full inspection of the interior and exterior of the complete air barrier envelope, to include readings of the roof. Document envelope areas that are inaccessible for testing. Use infrared thermography technology in concert with standard pressurization methods (blower doors, trailer mounted fans or the building's own air handling systems) to locate leaks

through the air barrier. Adjust the HVAC system, if possible, to create or enhance the temperature difference between the envelope interior and exterior. The minimum allowable temperature difference is 5 degree C 9 degrees 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 with the camera from inside the envelope, keep the envelope at a pressure differential of -20 Pa with respect to the outdoors using pressure testing equipment or the building's own air handling system.

3.9.6.4.2 Thermography Test Results

Document the location of all leaks, anomalies, and unusual thermal features on a floor plan or elevation view and catalog them with a visible light picture for locating the defect for correction. The thermographer is to recommend corrective actions to eliminate the leaks, anomalies, and unusual thermal features. Where leaks are found perform corrective sealing as necessary to achieve the whole envelope air leakage rate specified. After sealing, again use thermography in concert with standard pressurization methods to verify that the air leakage has been reduced. After these leaks have been permanently sealed, note all actions taken on the drawings or in the Thermographic Investigation Report. Submit the drawings for approval as part of the Thermographic Investigation Report. Also include thermographic photos that show where leaks were discovered. Include thermograms using an imaging palette that clearly shows the observed thermal patterns indicating air leakage. The Contracting Officer's Representative is to witness all testing.

3.9.6.5 Fog Test

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**NOTE: A fog generator is an electrical device that heats a water-based fluid and converts it into a safe, breathable and relatively buoyant fog. This fog can be issued towards a building interface from a distance of 6 m 20 feet or greater. Consumer grade fog generators are commonly used for parties or during the Halloween season.**

**********

Before using a theatrical fog generator, disable all building smoke detectors as they may alarm when fog is issued. Coordinate fog tests and the disabling of all smoke detectors with the Contracting Officer's representative and the local fire department as necessary. Use pressure test equipment or the buildings own air handling system to positively pressurize the building envelope to at least 25 Pa but not greater than 85 Pa over the outdoors. Using a theatrical fog generator within the envelope, direct fog at suspected leakage points such as at building interfaces. Test the following interfaces: roof/wall, wall/wall, floor/wall, wall/window, roof/mounted mechanical equipment. From the vantage point immediately outside the envelope and opposite that of the interface being tested, observe the effect as the fog is issued. Detection may also be further enhanced by using a scented fog liquid or a fog liquid that produces a colored fog. Look for fog and smell for associated odor percolating through the interface. Also use smoke puffers and smoke sticks as necessary to locate leaks at these and other interface locations. If the Architectural Plus HVAC System pressure test will be/was performed introduce fog into ductwork to check for leakage between

ductwork and associated dampers. After fog testing has ended, reactivate the building smoke detectors, and notify the Contracting Officer and local fire department that the test has ended. After sealing has been completed retest these areas using fog. Seal additional leaks that are found. (Note that theatrical fog may release quantities of the water vapor, glycol, mineral oil, or other media that could damage electronics and interior finishes or cause allergic reactions. Small scale smoke trace could be used as an alternative. See "Effects of Theatrical Smokes and Fogs on Respiratory Health in the Entertainment Industry" at www.nih.gov.)

3.9.6.6 Diagnostic Test Report

Once the diagnostic tests have been completed and the leakage locations identified and sealed, document these procedures, locations, and recommendations in the diagnostic test report. Submit plan and profile drawings that thoroughly identify leak locations. Describe in detail all leak locations so that the seal-up crew knows where to apply sealing measures. After sealing measures have been applied, describe the methods used along with applicable photos of the final sealed condition.

3.9.6.6.1 Thermographic Investigation Report

Submit a report of each thermographic investigation identifying the thermal discontinuities in the thermal control layer. Indicate in the final report locations to which improvements for both the air control layer and the thermal control layer were made to reduce air leaks and correct discontinuities in the thermal control layer. Include in the report some selected radiometric images of suspected failure points in the air barrier envelope that indicate before and after conditions.[ Devote a chapter(s) of the Thermographic Investigation Report to identifying suspected points of thermal bridging, moisture migration through roofs and walls, and insulation voids.] Indicate in the final report improvements that were made to the envelope to reduce air leaks. Include the following items in the report:

a. Brief description of the building construction

b. Types of interior and exterior surface materials used in the building.

c. Geographical orientation of the building with a description of the exterior surroundings including other buildings, vegetation, landscaping, and surface water drainage.

d. Camera brand, model and serial number, and most recent calibration date; optional lenses with serial numbers (if applicable)

e. Thermographer's and Government Inspector's names

f. Date and time of tests

g. Air temperature and humidity inside the air barrier envelope

h. Outdoor air temperature and humidity

i. General information for the last 12 hours on the solar radiation conditions in the geographic area where the test is being performed.

j. Ambient conditions such as precipitation and wind direction and speed occurring with the last 24 hours, as applicable. Refer to specific

requirements in each section of each thermographic inspection type for requirements in each specific area.

k. Documentation of those portions of the building envelope which were not within test conditions when the scan was performed, and which portions were obstructed by adjacent structures, interior furnishings, intervening cavities, or reflective surfaces.

l. Other relevant information, which may have influenced test results.

m. Drawings, sketches, floor plans and photographs detailing the locations in the buildings where thermograms were taken detailing possible irregularities in the components being tested.

n. Thermal images taken during the inspection with their relative locations and written or voiced recorded explanations of the anomaly listed along with visual and reference images.

o. An identification of the aspects or components of the building being examined.

p. Explanations for the type and the extent of each construction defect observed during the inspection.

q. Any results from additional measurements and investigations. Identify additional equipment used and support with type, model number, serial number, and date of most recent calibrated.

3.9.6.6.2 Fog Test Report

Document all turbulent air flow and dead air spaces within the envelope. Report fog behavior as it exits from or is entrained within the building. Include a floor plan in the report that documents the locations where fog passed through the envelope.

3.9.7 Calculation Program

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 A) into the Air Leakage Rate by Fan Pressurization Excel spreadsheet. This spreadsheet can be found at the following web site: http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphic

3.9.8 After Completion Of The Pressure And Diagnostic Test

After all pressure and diagnostic testing has been completed unseal all temporarily sealed items. Unless otherwise directed by the Contracting Officer, return all dampers, doors, and windows to their pre-test condition. Remove tape and plastic from all temporarily sealed openings, being careful not to deface painted surfaces. If paint is removed from finished surfaces, repaint to match existing surfaces. Unless otherwise directed by the Contracting Officer's representative, return fuel (gas) valves to their pre-test position and relight pilot lights. Return all fans and air handling units to pre-test conditions. Restore smoke/fire detectors to operating condition.

### 3.9.9 Repair And Protection

Repair and protection are the Contractor's responsibility, regardless of the assignment of responsibility for testing, inspection, and similar services. Upon completion of inspection, 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 TRAINING

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**NOTE: This Article contains tailoring options for KTR HIRED COMMISSIONING PROVIDER, and GOVT HIRED COMMISSIONING PROVIDER.**
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The Building Enclosure Commissioning Specialist must review the training plan required by Section 01 78 00 OPERATION AND MAINTENANCE DATA and identify any deficiencies to the Contracting Officer's Representative and the Contractor's Quality Control Personnel.

The Commissioning Provider is responsible for overseeing and approving the training plan required by Section 01 78 00 OPERATION AND MAINTENANCE DATA and identifying any deficiencies to the Contracting Officer's Representative and the Contractor's Quality Control Personnel.

Coordinate, schedule, and document training of all commissioned systems as required by Section 01 91 00.15 BUILDING COMMISSIONING paragraph titled "Training Plan".

## 3.11 FINAL BECx REPORT

The BECx must provide a final BECx report that includes information generated by the BECx process including: BECx meeting minutes, design reports, test reports, the final OPR, BoD, final BECx Plan, issue and resolution log, site observations, as-built drawings (provided by the Contractor), submittals, record of training, and recommended preventive maintenance actions and intervals.

The BECxP must ensure the Final BECx Report is submitted as a portion of the Final Commissioning Report for the project, as defined in Section 01 91 00.15 BUILDING COMMISSIONING. Submit report within 14 calendar days of completion of all commissioning efforts.

## 3.12 APPENDICES

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**NOTE: Download appendices from http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/for and insert as specified. Attachments to this section will be listed in the section table of contents generated through the SpecsIntact print process.**
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The following forms are available for download as a MS Word file at http://www.wbdg.org/ffc/dod/unified-facilities-guide-specifications-ufgs/forms-graphic

Appendix A - Air Leakage Test Form
Appendix B - Air Leakage Test Results Form
Appendix C - Test Agency Qualifications Sheet

-- End of Section --