Designation: E3158 – 18

Standard Test Method for Measuring the Air Leakage Rate of a Large or Multizone Building[1]

This standard is issued under the fixed designation E3158; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This standard test method provides a quantitative field-test procedure and calculation method for assessing an air leakage rate using a fan-induced pressure differential(s) across the building envelope, generated by blower doors or equivalent equipment.

1.2 Building setup conditions in accordance with defining the test boundaries appropriate for testing the envelope's air leakage are defined in this test method.

1.3 Procedure to determine the air pressure boundaries of the test envelope to be tested are provided in this test method.

1.4 This test method applies to all multizone and large building types and portions or subsections thereof.

1.5 This test method defines three test procedures: multi-point regression, repeated single point, and repeated two-point air leakage rate testing.

1.6 This test method allows for testing the test envelope in a pressurized condition, a depressurized condition, or in both conditions and averaging the results.

1.7 This test method applies to an air leakage rate specification with a reference pressure greater than 10 Pa (0.04 in. WC) and not greater than 100 Pa (0.40 in. WC).

1.8 This test method describes two methods of preparation for the building in order to conduct the test: the building envelope where HVAC-related openings are excluded, and on the operational envelope where the HVAC-related openings are included.

1.9 *Units*—The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.10 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E456 Terminology Relating to Quality and Statistics
E631 Terminology of Building Constructions
E779 Test Method for Determining Air Leakage Rate by Fan Pressurization
E1186 Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems
E1258 Test Method for Airflow Calibration of Fan Pressurization Devices
E1827 Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door
E2178 Test Method for Air Permeance of Building Materials
E2357 Test Method for Determining Air Leakage Rate of Air Barrier Assemblies

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of general terms related to building construction used in this test method, refer to Terminology E631 and for general terms related to accuracy, bias, precision, and uncertainty, refer to Terminology E456.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *baseline pressure, n*—internal test envelope pressure with the air movement equipment off and sealed, recorded while the building is configured for the test.

3.2.2 *building envelope, n*—defined boundary of the test sample to determine its air leakage rate excluding the HVAC-related devices (HVAC devices sealed).

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.3 *envelope pressure, n*—differential in air pressure across the envelope (that is, between a building or zone and the outdoors).

3.2.4 *equivalent leakage area (EqLA), n*—The cross-sectional area of a sharp-edged hole that would have the same leakage flow rate as the building if both were subjected to a 10 Pa indoor/outdoor pressure difference.

3.2.5 *HVAC, n*—heating ventilating and air conditioning.

3.2.6 *induced envelope pressure, n*—an internal envelope pressure caused by the operation of air moving equipment.

3.2.7 *multizone building, n*—building or enclosure that consists of more than one occupancy class or rating, separated by a boundary layer designed to control the movement of air between the different zones.

3.2.8 *normalized leakage area, n*—airflow rate measured that is normalized to the test envelope surface area (the test envelope boundary as defined in 9.1.1).

3.2.9 *operational envelope, n*—defined boundary of the sample to determine its air leakage rate that consists of the *building envelope*, and any HVAC-related penetrations.

3.2.9.1 *Discussion*—HVAC devices are shut off but left unsealed.

3.2.10 *single zone, n*—building, enclosure, or test envelope boundary, without any interior boundary layers that control the movement of air between different areas within that zone, or multiple zones configured to achieve a single zone condition.

3.2.11 *single zone condition, n*—condition when the internal pressure within a defined space or test envelope boundary differs by no more than 10 % when measured anywhere within that zone.

3.2.12 *specified air leakage rate, n*—maximum allowable airflow rate from a specified induce pressure differential into a building envelope or test zone boundary, expressed in $L/(s \cdot m^2)$ at 75 Pa.

3.2.13 *specified reference pressure, n*—the induced test envelope pressure at which the results are required to be reported by the project specification.

3.2.14 *test envelope, n*—boundary of a building or a portion of a building that is configured to a single zone condition to be tested, as defined by the consultant.

3.2.15 *test pressure, n*—induced pressure (not baseline adjusted) into the test envelope, measured while test fans are in operation.

4. Summary of Test Method

4.1 This test method provides quantitative test and analysis methods to determine whether a building envelope has met a specified air leakage rate (defined by others). During the test, the total airflow through the test fans and corresponding induced envelope pressures are measured. The relationship between the airflows and induced pressures are used to measure the air leakage rate of the envelope. Specifications for air leakage rates of an envelope are written in terms of the maximum allowable airflow rate from a specified induce pressure differential.

4.2 This test method describes the methods consisting of multipoint regression, repeated single point and repeated two-point pressure testing, mechanically inducing a pressure differential between the test envelope and any surrounding zones, the exterior, or another environment. Different preparation of the building's mechanical systems allows for both the building envelope and the operational envelope to be tested. Test parameters allow the test to be conducted on large or multizone buildings within defined weather conditions.

5. Significance and Use

5.1 This test method does not establish requirements for airtightness but provides means of assessing compliance with specified air-leakage rates established elsewhere.

5.2 This test method is used to determine the airtightness of building envelopes or portions thereof by measuring the air leakage rate at specified reference pressure differentials.

5.3 This test method provides:

5.3.1 Specific directions for determining acceptable weather conditions for conducting the test.

5.3.2 Two different test boundary preparation conditions; building envelope (9.1.1.1), and operational envelope (9.1.1.2).

5.3.3 Testing conducted in a range of pressures from 10 Pa (0.04 in. WC) to 100 Pa (0.40 in. WC).

5.4 A measurement of the air-leakage rate of the constructed building envelope. Test methods that measure the air permeance of materials (Test Method E2178) and air leakage of assemblies (Test Method E2357) alone do not address the various complexities of the constructed building envelope, including but not limited to design, sequence, constructability, workmanship, and the transitions between assemblies.

5.5 This test method applies to all multizone and large building types and portions or subsections of buildings. It can be used to test envelopes that consist of a single zone or subsections of a zone that can be tested as a single zone. Test envelopes that are entirely composed of subsections separated by interior partitions or floors, or both, may be tested as a single zone by maintaining baseline relationships between these subsections throughout testing. (See Appendix X1. See also Test Methods E779 and E1827.) Isolated subsections, each with its own specified air-leakage rate, shall be treated as separate test envelopes and tested separately. While testing isolated subsections, monitoring must be conducted for any extraneous/flanking air movement between the different zones.

5.6 The building preparations prior to testing (fenestration positions and preparation of intentional openings such as HVAC penetrations and equipment) are critically important and can have a strong influence on the final test results. This test method includes guidance for testing of the building envelope both including and excluding HVAC-related openings.

5.7 Compliance with a specified air leakage rate does not imply that all potentially problematic leaks have been sealed.

5.8 While this test determines the air leakage rate of an envelope, it does not identify the location of leakage sites.

NOTE 1—See, for example, Practices E1186 for locating leaks. The location of leaks, in addition to their cumulative leakage area, is also an important determinant of leakage under normal operating conditions.

6. Apparatus

6.1 The following is a general description of the required apparatus. Any arrangement of equipment using the same principles and capable of performing the test procedure within the allowable tolerances shall be permitted.

6.2 *Major Components:*

6.2.1 *Air-Moving Equipment*—Fans, blowers, blower door assemblies, or HVAC air movement components that are capable of moving air into and out of the conditioned space at the required airflow rates under a prescribed range of induced test pressure differentials. The system shall provide control of airflow sufficient to perform the selected test sequence (See Section 9).

NOTE 2—If using the HVAC system as the air movement equipment for the test, then the test is limited to only the Building Envelope (HVAC-related openings excluded) configuration, and not the Operational Envelope configuration, see 9.1.1.

6.2.2 *Pressure Gauges,* shall be digital with a resolution of 0.1 Pa (0.0004 in. WC) and accurate to within ±1 % of reading or ±0.25 Pa (0.001 in. WC), whichever is greater, and shall have a means of adjusting time averaging intervals. Pressure gauges shall measure a minimum of two samples per second. Pressure gauges shall measure pressure and flow simultaneously. Gauges shall be checked, and their accuracy verified at intervals in accordance with the manufacturer's recommendations. Follow manufacturers' recommendations for field check procedures.

6.2.3 For each test fan configuration, airflow-measuring devices shall be accurate to within ±5 % of reading. Test fans shall be checked, and their accuracy verified at intervals in accordance with the manufacturer's recommendations. Follow the manufacturer's recommendations for field inspection procedures.

6.2.4 *Temperature-Measuring Device*—Instrument to measure temperature with an accuracy of ±2 °C (4 °F).

7. Hazards

7.1 *Personal Protective Equipment*—On active construction sites, the testing team personnel shall wear eye protection, hard hats, and safety shoes, and other safety equipment as required by local regulations.

7.2 *Fall Protection*—Testing team personnel shall be trained in fall protection and proper equipment such as ladders, aerial lifts, scissor lifts, stages, scaffolds while working at elevated areas.

7.3 *Noise*—Hearing protection shall be available to testing team personnel exposed to fan noise.

7.4 *Equipment Guards*—Air moving equipment shall have proper guards or cages to house the fan or blower and to prevent access to any moving parts of the equipment.

7.5 *Safety, Security, and Fire*—Consideration shall be given for adequate security and fire protection measures during testing. This would include, but not be limited to, security for the building, the equipment, placement of signage, and barricades for hazard protection, and considerations for fire spread changes with the opening of fire doors, dampers, vents, and alteration of fire zones during the duration of the testing.

7.5.1 Note that alterations to fire spread should be authorized by the Authority Having Jurisdiction (AHJ) as a stakeholder participant in the process. A fire watch, change in response time, or other measures may be necessary as approved by the AHJ.

7.6 *Debris, Fumes, and Temperature*—The blower or fan equipment used to pressurize or depressurize the test envelope presents hazards to the interior not limited to dust, debris, indoor air quality, occupancy, occupant comfort, plants, furnishings, finishes, and artwork. These hazards can be minimized by the location of the test fans.

7.7 *Combustion Appliances*—Adjust all combustion appliances so they do not turn on during the test. This is commonly done by temporarily turning off power to the appliance, or setting the appliance to the "Pilot" setting. Open solid fuel burning fireplaces shall be clear of ashes.

7.8 *Elevators*—Ensure, if elevator doors are open, that there are handrail barriers across the openings on each floor and the elevators are locked out and not operational.

7.9 *Existing Condition Hazards*—Test should not be conducted when the building is known or suspected to have potentially hazardous materials, such as but not limited to, asbestos, lead, or mold, until Authority Having Jurisdiction has approved the use of a pressurization/depressurization test.

7.10 *Egress*—When the building is subject to induced pressures, exterior doors have the ability to burst open if not locked and secured. All egress access points shall be clearly marked with signage indicating the danger and that a test is in progress.

7.11 *This section describes hazards related to performing these tests but does not purport to address all possible hazards. Refer to 1.10 for further guidance.*

8. Calibration and Standardization

8.1 Pressure gauges shall be calibrated against a National Institute of Standards and Technology (NIST) traceable standard over at least 16 pressures in a range from at least +250 to –250 Pa (1.0 in. WC) or to the greatest pressure used during a test. The minimum (absolute value) calibration pressures shall be no greater than 25 Pa (0.10 in. WC).

8.2 Airflow measuring devices shall be calibrated in compliance with Test Method E1258 at a minimum of three flow rates where one is above or within 10 % of the maximum flow measured during the test and one is below or within 10 % of the minimum flow measured during the test. Calibration at each of these three flow rates shall be performed at three backpressures (induced pressures) where one calibration point is above or within 10 % of the maximum backpressure measured and one is below or within 10 % of the minimum backpressure measured.

8.3 Digital pressure gauges and test fans are permitted to be calibrated separately and used interchangeably if they meet the requirements of 6.2.3.

9. Procedure

9.1 *Establish Test Objectives*—Determine the specified air leakage rate and any other associated information required based on the test specifications located within the construction documents for the project. If not specified, clarification is required from the client or the entity who has requested the test to be conducted.

9.1.1 Determine the configuration of the envelope to be tested, it can be either/or and or both:

9.1.1.1 Building envelope (HVAC-related openings excluded).

9.1.1.2 Operational envelope (building envelope and HVAC-related openings included).

9.1.2 Identify whether the test is for:

9.1.2.1 A single zone, two or more subsections tested as a single zone, or isolated subsections tested independently.

9.1.3 Three conditions are available when conducting the test:

9.1.3.1 Pressurization only.

9.1.3.2 Depressurization only.

9.1.3.3 Pressurization and depressurization with the results averaged.

9.1.4 Identify whether the test will be conducted using:

9.1.4.1 The regression method,

9.1.4.2 Single-point method, or

9.1.4.3 The two-point method.

9.1.5 Identify the boundaries of the envelope that shall be tested from 9.1.1.

9.1.5.1 Review available construction documents, including but not limited to, architectural drawings and mechanical schedules.

9.1.5.2 In narrative or on floor plans, identify the location of the walls, floors, ceilings, and roof assemblies bounding the test envelope.

(1) Make a list of identified ancillary spaces to adopt into a test plan such as, but not limited to, mechanical rooms, elevator equipment rooms, loading docks, crawlspaces, basements, service tunnels, and attics.

(2) Include an ancillary space within the test envelope if it is thermally separated from outdoors (for example, by assemblies that include insulation and continuous air barriers) and is not thermally separated from adjoining indoor portions of the test envelope.

(3) Do not include an ancillary space within the test envelope if it is thermally separated from all adjoining portions of the test envelope and is vented to the exterior by passive openings that do not include motorized or gravity dampers.

(4) Many older commercial, institutional, and industrial buildings have separate mechanical rooms that contain boilers connected to multistory chimneys; these spaces often include passive or fan powered make-up air inlets. In this case, treat the boiler room as a separate space which is outside the test envelope.

(5) Determine building preparations required for intentional openings based on 9.1.5.

(6) Determine whether the HVAC systems can be set as required for the test.

9.2 *Coordinate* the test with the building owner, manager, or authorized representative.

9.2.1 Identify dates for conducting the test when the following requirements can be met:

9.2.1.1 Lowest occupancy rates are expected, for example, weekends, holidays, and evenings.

9.2.1.2 The owner or their representative with authorized access to all spaces in the test envelope shall be present.

9.2.1.3 Person authorized by the building owner or their representative to set mechanical equipment to the mode required for the test shall be present (for example, place motorized dampers in the closed position, de-energize exhaust and dedicated make-up air fans, and turn off required combustion appliances).

9.2.1.4 Person authorized by the building owner or their representative to reset breakers if need be.

9.2.2 Inform the building contact person that the test may be canceled due to high wind speeds, gusting winds, or large indoor/outdoor temperature differences.

9.2.3 *Arrange Security Procedures*—Develop a security plan to address security issues, identify safety, security, and privacy concerns, and identify any areas where interior doors cannot be opened under any circumstances or opening doors may be a safety, privacy, or security issue.

9.3 *Building or Envelope Preparation*—Prior to preparing the building for testing, determine if weather conditions will be likely to prohibit testing. Conditions shall meet requirements in Section 10. High winds, gusty winds, and a combination of a tall building and large indoor-outdoor temperature differential, are factors which may prohibit testing. (See X1.3 to X1.5.2.)

9.3.1 *Building Envelope Test* (HVAC-related openings excluded):

9.3.1.1 Windows and exterior doors shall be closed and latched or locked. Interior partition doors to adjoining portions within the test envelope shall be open.

9.3.1.2 From the list of intentional openings created in 9.1.5, prepare the openings as determined and record how the openings were prepared. Note any observed deviations from the list.

9.3.2 *Operational Envelope Test* (building envelope and HVAC-related openings included):

9.3.2.1 Windows and exterior doors shall be closed and latched or locked. Interior partition doors shall be in their regular operable positions, as they would be during normal occupancy of the building.

9.3.2.2 From the list of intentional openings created in 9.1.5 prepare the openings as determined and record how the openings were prepared. Note any observed deviations from the list.

NOTE 3—In the case of a Multi Unit Residential Building (MURB), individual suite doors off the main corridors would remain closed, and the doors located within the individual suites would remain open during the Operational Envelope Test.

9.3.2.3 Determine how the airflow needed to conduct the test will be provided and measured at the test site.

9.3.3 Determine whether the building is ready to be tested:

9.3.3.1 Determine if weather conditions will be likely to prohibit testing.

9.3.3.2 Inspect the building to determine whether the designated test envelope is complete for testing in accordance with 9.1.5. Record any HVAC-related openings found in the building that were not identified in 9.1.5 and the status of associated fans, dampers, and temporary sealing during the test.

9.3.3.3 Fill dry plumbing traps.

9.3.3.4 Turn off all combustion equipment, where practical, identified in Table 1 and document any combustion equipment which cannot be turned off.

9.3.3.5 Turn off all exhaust and make-up air fans.

9.3.3.6 Turn off all air handlers and fans identified to be de-energized from Table 1 developed in 9.1.5.

NOTE 4—Air handlers and fans that were not de-energized may have an adverse effect on the test and may be de-energized to enable testing.

9.3.3.7 Confirm that effective distribution of test airflow is meeting single zone requirements within the test envelope.

NOTE 5—Interior doors may remain closed if it has been demonstrated that closing them has insignificant impact on the test result (for example, pressure monitoring demonstrates that the space meets single zone requirements). Interior doors may also be closed to manage airflow so that the single zone condition is achieved.

9.4 *Deploy Test Equipment:*

9.4.1 *Envelope Pressure Measurements*—Place pressure gauges, sensing tubes, and electronic data acquisition equipment to measure the envelope pressure.

9.4.1.1 Envelope pressure measurements shall be made across one or more walls. When made across more than one wall, the pressure taps shall be connected to a manifold, in order to create a single exterior pressure measurement or

TABLE 1 Building Preparation for Test Boundary

Intentional Openings	Building Envelope (HVAC-related openings excluded)	Operational Envelope (building envelope and HVAC-related openings included)
Interior doors, hatches, and operable windows inside the test envelope, which are closed during normal building operation[A]	Open	Closed & latched
Interior fire doors within the test envelope	Open	Open
Interior common stairwell doors within the test envelope	Open	Open
Fire Dampers	Remain as found	Remain as found
Windows, doors, skylights, and hatches in the bounding envelope	Closed and latched	Closed and latched
Windows, doors, hatches, and operable windows in ancillary spaces as identified in section 9.1.5.2*(1)*	Treat in accordance with 9.1.5.2*(1)*	Treat in accordance with 9.1.5.2*(1)*
Dryer doors and air handler access panels	Closed and latched	Closed and latched
Vented combustion appliance	Off, unable to fire	Off, unable to fire
Pilot light	As found	As found
Chimney or outlet for vented combustion device in a separate mechanical room	As found	As found
B-vent or other insulated chimney serving a vented combustion appliance located within the test envelope	Sealed[B,C]	As found
Solid fuel appliances (fireplaces, wood burning stoves, pellet stoves)	No fires; dampers closed; chimney sealed[B,C]	No fires; dampers closed
Exhaust, outdoor air, make-up air fans, air handlers that serve areas inside and outside the test envelope	Off	Off
Clothes dryers	Off	Off
Air intake inlet with motorized dampers	Dampers closed and sealed[B,C]	Dampers closed
Air intake inlet with gravity dampers	Sealed[B,C]	As found
Air intake inlet with no dampers	Sealed[B,C]	Open unless fan(s) serving inlet is operated greater than 8000 h per year, then sealed[B,C]
Exhaust or relief air outlet with motorized dampers	Dampers closed and sealed[B,C]	Dampers closed
Exhaust or relief air outlet with gravity dampers	Sealed[B,C]	As found
Exhaust or relief air outlet with no damper	Sealed[B,C]	Open unless fan serving outlet is operated greater than 8000 h per year, then sealed[B,C]
Active or passive smoke control systems - air reliefs and intakes	Sealed[B,C]	As found
Intended powered or non-powered openings for vented shafts/stairwells	Sealed[B,C]	As found
Waste or linen handling systems and equipment	Sealed[B,C] at rooftop chute vent opening.	Rooftop chute vent – open, chute intake doors – closed, chute intake room and chute discharge room doors – closed and latched, fire dampers - left as found
Clothes dryer outlets	Sealed[B,C]	As found; sealed[B,C] if dryers are not yet installed
Exhaust, outdoor air, or make-up air fan that runs >8000 h per year	Sealed[B,C]	Sealed[B,C]
Ductwork that serves areas inside and outside the test envelope	Sealed[B,C] at supply and return	Sealed[B,C] at supply and return
Floor drains and plumbing	Traps filled	Traps filled

[A] Interior doors, hatches, and operable windows shall be left open if closing them significantly restricts proper distribution of pressure differentials across the test envelope.
[B] Sealed means that an opening has been temporarily masked airtight (for example, covered with self-adhering plastic film, taped polyethylene film, or rigid board stock). See Appendix X1.
[C] If the test result meets the passing criteria for the method used, then the building is deemed to pass even if not all of the HVAC-related openings were sealed during the test.

measured individually and the resulting multiple measurements averaged arithmetically. Exterior pressure taps shall be mounted within 0.5 m vertically of grade level, in contact with the exterior wall of the building, and within 1 m of the horizontal center of the wall. Exterior pressure taps shall not be moved vertically in order to locate the neutral pressure level to satisfy the requirements in Eq 1. See Appendix X1 for further recommendations.

9.4.2 *Test Fans*—Install test fans in exterior door or window openings. Follow manufacturer's instructions for setting up test equipment. During windy conditions, set up the fan in a sheltered or guarded location. Locate test fans so that a single zone condition is created. See Appendix X1.

9.4.3 *Internal Induced Pressure Uniformity Measurements*—Place pressure gauges and sensing tubes to measure the maximum air pressure differentials between different sections of the test envelope.

NOTE 6—For example, significant pressure differentials can exist between different sections of the test envelope if there are barriers to airflow (for example, walls or floors with either no intentional openings or intentional openings that have a small enough area that the expected airflow through them will induce significant pressure drop).

9.4.3.1 In the case of buildings without interior restrictions, such as warehouses or buildings with central atria, no measurements are required to confirm the uniform internal pressure. In buildings consisting of multiple zones connected by 2 m^2 (21.5 ft^2) openings (or smaller), measurements shall be made to determine, and if a single zone condition is achieved.

9.4.3.2 In multistory buildings, measurements shall be made every ten stories and include the top floor, bottom floor, and middle floor at a minimum. If all the rooms in a test envelope are interconnected with 2 m^2 openings (or larger) and total test fan airflow at the highest induced test pressure is less than 2800 L/s (6000 CFM), then pressure uniformity can be assumed, and no pressure uniformity measurements are required. These measurements will be used to inform the test technician and allow them to take measures to maintain single zone pressure conditions during the test. See Appendix X1.

10. Calculation or Interpretation of Results

10.1 *Collect and Analyze Data for Multi-Point Regression Test:*

10.1.1 *Pre-test Baseline Pressure*—All the test fans shall be turned off and sealed for at least 30 s after which a pre-test baseline pressure measurement of at least 120 s duration shall be recorded. Baseline measurements shall be the temporal average of the baseline data from all envelope pressure locations. When analyzing the data, use the same envelope pressure locations for all baseline envelope pressures and unadjusted envelope pressures. Divide the baseline into 12 equal length intervals. Calculate the temporal average of each interval and the standard deviation of these averages. The baseline standard deviation (STDev ($P_{base,pre}$)) is used in Eq 1 to calculate the minimum allowable induced envelope pressure.

10.1.2 Measure and record the pre-test indoor and outdoor air temperature and wind speed. Determine the site altitude above mean sea level within 100 m (300 ft).

10.1.3 *Unadjusted Envelope Pressures and Flow Measurements*—Measure and record the airflows through all operating test fans for a series of at least ten approximately equally spaced unadjusted envelope pressures. Each unadjusted envelope pressure and its corresponding flow measurements from all fans shall occur within 20 s of each other. Each induced envelope pressure shall be averaged over a minimum of two times the length of the equal length intervals in 10.1.1. There shall be at least a 25 Pa (0.1 in. WC) differential between the lowest and highest induced envelope pressures. Calculate the minimum induced envelope pressure using the following equation:

$$P_{induced,min} \geq Max\left(|P_{base,pre}| + 10xSTDev(P_{base,pre}),\ \frac{P_{stack}}{2},\ 10\ Pa \right) \quad (1)$$

where:

$P_{induced,min}$ = the minimum induced envelope pressure that may used in the test analysis,
$P_{base,pre}$ = the pre-test baseline envelope pressure, and
P_{stack} = the total calculated stack pressure given by Eq 2.

$$P_{stack} = abs(\rho_{out} - \rho_{in}) \cdot g \cdot h \quad (2)$$

where:

ρ_{in} = inside air density (kg/m^3) given by Eq A2.1,
ρ_{out} = outside air density (kg/m^3) given by Eq A2.2,
g = acceleration of gravity as 9.81 m/s^2, and
h = height of building (m), measured from grade up to highest portion of the test envelope.

10.1.4 Under windy conditions (wind speeds of 20 km/h (12 mph) or greater from the nearest airport weather station or measured at the site) it is recommended to repeat using a longer pre-test baseline. In no instance shall the induced envelope pressure be lower than 10 Pa (0.04 in. WC) or greater than 100 Pa (0.40 in. WC). For a test to be valid, the absolute value of the largest induced envelope pressure shall be greater than 0.90 times the absolute value of the specified reference pressure.

10.1.5 *Maintain Single Zone Condition*—Pressure differences within the test envelope shall be measured and recorded. For a test point to be used in the analysis, the difference between the highest and lowest pressure difference within the test envelope shall be no more than ±10 % of the induced envelope pressure. Make any corrections needed to maintain a single zone condition. Exception: if uniformity was not maintained within 10 % during a test, the building may be deemed to pass if the test specification is met when the results are analyzed using only the building envelope pressure measurements made at the location of the induced envelope pressure differential with the smallest absolute value.

10.1.6 *Post-test Baseline Pressure*—All the test fans shall be turned off and sealed for at least 30 s, after which a post-test baseline pressure measurement of at least 120 s duration shall be recorded. Baseline measurements shall be the temporal average of the baseline data averaged over all envelope pressure locations.

10.1.7 *Pressurization and Depressurization*—Repeat 10.1.1 through 10.1.6 for each required test mode (depressurization or pressurization, or both). When performing both pressurization and depressurization measurements, record the pressurization and depressurization data separately including all preliminary environmental measurements and baseline readings as if performing two separate or individual tests.

10.1.8 *Data Analysis and Calculations:*

10.1.8.1 Data shall be analyzed in accordance with Annex A1 (un-weighted regression).

10.1.9 For each test, if the calculated pressure exponent, *n*, is less than 0.45 or greater than 1.05, the test is invalid. If *n* is less than 0.5 or greater than 0.9, check test envelope setup to determine whether openings have inadvertently opened or closed during the test. If a problem is found, correct the problem and retest. See Appendix X1 for discussion of this issue.

10.1.10 If specified to use r^2, the value shall be no less than 0.98. If r^2 is less than 0.98, review the testing procedure, data, and envelope setup, to eliminate any problems. Take corrective action as needed. See Appendix X1 for discussion of this issue and calculations.

10.1.11 The test is not considered valid if the calculated flow at the specified reference pressure as determined in construction documents is:

10.1.11.1 Greater than the specified air leakage rate;

10.1.11.2 Exhausted from or supplied to the test envelope, and the induced envelope pressure is less than 90 % of the specified reference pressure;

10.1.11.3 Less than or equal to the specified air leakage rate and the 95 % confidence interval is greater than 8 %, and the sum of the test result and the 95 % CI is greater than the specified air leakage rate.

10.1.12 The test is considered valid if the calculated flow at the specified reference pressure as determined in the construction documents is:

10.1.12.1 Less than or equal to the specified air leakage rate and the 95 % confidence interval (CI) of the flow at the specified reference pressure is less than or equal to 8 % of the specified air leakage rate.

10.1.13 Test result will be reported in specified units along with 95 % CI.

10.2 *Collect and Analyze Data for Repeated Single Point Test:*

10.2.1 *Pre-test Baseline Pressure*—All the test fans shall be turned off and sealed for at least 30 s after which a pre-test baseline pressure measurement of at least 120 s duration shall be recorded. Baseline measurements shall be the temporal average of the baseline data from all envelope pressure locations. When analyzing the data, use the same envelope pressure locations for all baseline envelope pressures and induced envelope pressures. Divide the baseline into 12 equal length intervals. Calculate the temporal average of each interval and the standard deviation of these averages. The baseline standard deviation (STDev ($P_{base,pre}$)) is used in Eq 1 to calculate the minimum allowable induced envelope pressure.

10.2.2 *Baseline Pressure*—Before each measurement at the induced envelope pressure, all the test fans shall be turned off and sealed for at least 30 s or until the building envelope pressures stabilize, after which a baseline pressure measurement of at least two times the length of the equal length intervals in 10.2.1 shall be recorded. Baseline measurements shall be the temporal average of the baseline data from all envelope pressure locations.

10.2.3 Alternately baseline measurements may be collected before and after the replicate set of induced envelope pressure tests described in 10.2.5 as follows:

10.2.3.1 *Pre-test Baseline Pressure*—As defined in 10.2.1.

10.2.3.2 *Post-test Baseline*—All the test fans shall be turned off and sealed for at least 30 s, after which a post-test baseline pressure measurement of the same duration as the pre-test baseline shall be recorded. Baseline measurements shall be the temporal average of the baseline data averaged over all envelope pressure locations.

10.2.4 Measure and record the indoor and outdoor temperature and wind speed. Determine the site altitude above mean sea level within 300 ft (100 m).

10.2.5 *Induced Envelope Pressure and Flow Measurements*—The specified reference pressure shall be as determined in 9.1. If no induced test pressure is specified, test at 75 Pa (0.30 in. WC). Measure and record the airflows through all operating test fans for at least five replicate induced envelope pressures. Each induced envelope pressure and its corresponding flow measurement shall occur within 20 s of each other. Each induced envelope pressure shall be averaged over a minimum of two times the length of the equal length intervals in 10.2.1. Airflow measurements shall be the sum of the airflows through all operating test fans. For the Repeated Single Point test, induced, min is the reference envelope pressure of the specified air leakage rate. It shall be no lower than 10 Pa (0.04 in. WC) and no greater than 100 Pa (0.40 in. WC) and is calculated using the minimum induced envelope pressure using Eq 1. Under windy conditions, if this condition is not met, it is recommended to repeat using a longer pre-test baseline (see Appendix X1 for additional guidance).

10.2.6 *Maintain Single Zone Condition*—Pressure differences within the test envelope shall be measured and recorded. For a test point to be used in the analysis, the difference between the highest and lowest pressure difference within the test envelope shall be within 10 % of the induced envelope pressure. Make any corrections needed to maintain single zone requirements. Exception: if uniformity was not maintained within 10 % during a test, the building may be deemed to pass if the test specification is met when the results are analyzed using only the building envelope pressure measurements made at the location with the induced envelope pressure differential with the smallest absolute value.

10.2.7 *Pressurization and Depressurization*—Repeat 10.2.1 through 10.2.6 for each required test mode (depressurization or pressurization, or both). When performing pressurization and depressurization measurements, record the pressurization and depressurization data separately, including all preliminary environmental measurements and baseline readings as if you were performing two separate or individual tests.

10.2.8 *Data Analysis and Calculations*—If the airflow required to meet the specified reference pressure as determined in

9.1 is exhausted from or supplied to the test envelope, and the induced envelope pressure is less than 90 % of the specified reference pressure, the test is not considered valid.

10.2.9 Data shall be analyzed in accordance with Annex A4 or the specified reference pressure if different than 50 to 75 Pa (0.20 to 0.30 in. WC). Please refer to A1.2 for calculations.

NOTE 7—If the pre-test and post-test baseline alternate is chosen, there are two baseline measurements for the test: one before the entire set of replicate induced envelope pressures, and one after. In this case use the average of the pre-test and post-test baseline measurements as the average baseline for all replicate measurements at the induced envelope pressure.

10.2.10 For a test envelope to pass, each induced envelope pressure shall be within 10 % of the specified induced envelope pressure.

10.2.11 Document if the calculated flow at the specified reference pressure is:

10.2.11.1 Greater than the specified air leakage rate;

10.2.11.2 Less than or equal to the specified air leakage rate and the overall uncertainty Eq 3 in 12.1 is less than or equal to 8 % of the specified air leakage rate;

10.2.11.3 Less than or equal to the specified air leakage rate and the overall uncertainty Eq 3 in 12.1 is greater than 8 % and the sum of the test result and the overall uncertainty is less than or equal to the specified air leakage rate;

10.2.11.4 Less than or equal to the specified air leakage rate and the overall uncertainty Eq 3 in 12.1 is greater than 8 % and the sum of the test result and the overall uncertainty is greater than the specified air leakage rate.

10.2.12 Test result will be reported in specified units along with the overall uncertainty.

10.3 *Collect and Analyze Data for Repeated Two-Point Test:*

10.3.1 *Pre-test Baseline Pressure*—All the test fans shall be turned off and sealed for at least 30 s after which a pre-test baseline pressure measurement of at least 120 s duration shall be recorded. Baseline measurements shall be the temporal average of the baseline data from all envelope pressure locations. When analyzing the data, use the same envelope pressure locations for all baseline envelope pressures and induced envelope pressures. Divide the baseline into 12 equal length intervals. Calculate the temporal average of each interval and the standard deviation of these averages. The baseline standard deviation ($STDev(P_{base,pre})$ is used in Eq 1 to calculate the minimum allowable induced envelope pressure.

10.3.2 *Baseline Pressure*—Before each measurement at the induced envelope pressure, all the test fans shall be turned off and sealed for at least 30 s or until the building envelope pressures stabilize, after which a baseline pressure measurement of at least two times the length of the equal length intervals in 10.3.1 shall be recorded. Baseline measurements shall be the temporal average of the baseline data from all envelope pressure locations.

10.3.3 Alternately baseline measurements may be collected before and after the replicate set of induced envelope pressure measurements described in 10.3.4 as follows:

10.3.3.1 *Pre-test Baseline Pressure*—As defined in 10.3.1.

10.3.3.2 *Post-test Baseline*—All the test fans shall be turned off and sealed for at least 30 s, after which a post-test baseline pressure measurement of the same duration as the pre-test baseline shall be recorded. Baseline measurements shall be the temporal average of the baseline data averaged over all envelope pressure locations.

10.3.4 *Induced Envelope Pressures and Flow Measurements*—Measure and record the airflows through all operating test fans for two induced envelope pressures, a primary and secondary induced pressure (P1and P2). If P1 is not specified, assume 75 Pa (0.03 in. WC) for P1. A minimum of five replicate measurements of pressure and airflow at the primary induced pressure and the secondary induced pressure are required. Ensure enough time has been given between readings to ensure the induced pressure has stabilized. Each induced envelope pressure and its corresponding flow measurement shall occur within 20 s of each other. Calculate the minimum induced envelope pressure using Eq 1. For the Repeated Two-point test $P_{induced}$, min is P2, the secondary induced envelope pressure. Under windy conditions, if this condition is not met, it is recommended to repeat using a longer pre-test baseline (see Appendix X1 for additional guidance). P2 shall not be greater than one-third of the primary induced pressure P1. Therefore, the sequence of testing shall be the primary induced pressure, P1 followed by the secondary induced pressure P2, in order to establish P2. Each induced envelope pressure shall be averaged over a minimum of two times the length of the equal length intervals in 10.3.1. Induced envelope pressures shall be no lower than 10 Pa (0.04 in. WC) and no greater than 100 Pa (0.40 in. WC). Airflow measurements shall be the sum of the airflows through all operating test fans.

10.3.5 Test results P1 or P2 shall be within 10 % of the specified reference pressure and with a calculated pressure exponent, *n*, between the values of 0.45 and 1.05. If the primary induced envelope pressure is not within 10 % of the specified reference pressure, but the pressure exponent is within the allowable range, the test results may be deemed as a legitimate test. If *n* is less than 0.5 or greater than 0.9, check test envelope setup to determine whether openings have inadvertently opened or closed during the test. If a problem is found, correct the problem and retest. (See Appendix X1 for discussion of this issue.)

10.3.6 *Maintain Single Zone Condition*—Pressure differences within the test envelope shall be monitored and recorded. For a test point to be used in the analysis, the difference between the highest and lowest pressure difference within the test envelope shall be within 10 % of the induced envelope pressure. Make any corrections needed to maintain single zone requirements. Exception: if uniformity was not maintained within 10 % during a test, the building may be deemed to pass if the test specification is met when the results are analyzed using only the building envelope pressure measurements made at the location with the induced envelope pressure differential with the smallest absolute value.

10.3.7 *Pressurization and Depressurization*—Repeat 10.3.1 through 10.3.6 for each required test mode (depressurization or pressurization, or both). When performing both pressurization and depressurization measurements, record the pressurization and depressurization data separately, including all preliminary

environmental measurements and baseline readings as if you were performing two separate or individual tests.

10.3.8 *Data Analysis and Calculations*—If the airflow required to meet the specified test envelope pressure as determined in 9.1 is exhausted or supplied to the test envelope, and the induced envelope pressure is less than 90 % of the specified reference pressure, the building is deemed to fail.

10.3.9 Data shall be analyzed in accordance with Annex A4.

NOTE 8—If the pre-test and post-test baseline alternate is chosen, there are two baseline measurements for the test: one before the entire set of replicate induced envelope pressures, and one after. In this case, use the average of the pre-test and post-test baseline measurements as the average baseline for all replicate measurements at the primary induced envelope pressure and the secondary induced envelope.

10.3.10 Document if the calculated flow at the specified reference pressure is:

10.3.10.1 Greater than the specified air leakage rate;

10.3.10.2 Less than or equal to the specified air leakage rate and Eq 3 is less than or equal to 8 % of the specified air leakage rate;

10.3.10.3 Less than or equal to the specified air leakage rate and Eq 3 is greater than 8 % and the sum of the test result and the overall uncertainty is less than or equal to the specified air leakage rate;

10.3.10.4 Less than or equal to the specified air leakage rate and Eq 3 is greater than 8 % and the sum of the test result and the overall uncertainty is greater than the specified air leakage rate.

10.3.11 Test results shall be reported in specified units along with the overall uncertainty.

11. Report

11.1 The following items are required to be reported by the individuals performing the test:

11.1.1 Testing agency.

11.1.2 Client name.

11.1.2.1 Client address.

11.1.3 Primary point of contact for testing personnel.

11.1.3.1 Name of person(s) conducting test.

11.1.4 Test Envelope Description including construction status of items that impact results.

11.1.4.1 Address of testing site.

11.1.4.2 Elevation above sea level.

11.1.4.3 Building dimensions as required by test specifications (for example, surface area of test envelope and volume of test envelope) and person responsible for computation thereof.

11.1.5 Test Results.

11.1.5.1 Identification of test envelope boundaries.

11.1.6 If available, reference the air barrier specific pages in the construction documents, and any modifications thereof. In the event of no air barrier specific pages in the construction documents, identify test boundaries on floor plans and section drawings as actually tested. In the event there are no construction documents, provide a diagram or illustration showing the location of test envelope boundaries.

11.1.6.1 Document whether the test is for a single zone, two or more subsections tested as a single zone, or multiple isolated subsections tested independently.

11.1.6.2 Test configuration of intentional openings in the test envelope including:

11.1.6.3 Position of windows, doors, and other areas for access (open or closed position),

11.1.6.4 Mechanical System Related Penetrations (for example, louvers, grilles, rooftop and wall-mounted fans, air distribution ductwork that serves areas both inside and outside of the test envelope),

(1) Masked/unmasked,

(2) Location of masking,

11.1.6.5 Plumbing traps (filled with water or otherwise sealed).

11.1.7 Deviations from planned test envelope configuration and reasons for deviation.

11.1.8 Test configuration of all HVAC equipment: whether disabled or left running during test.

11.1.9 Statement of the purpose for conducting the test and the test procedure used.

11.1.9.1 Purpose of test (for example, building envelope test or operational envelope test).

11.1.9.2 Type of test (for example, repeated single point, repeated two-point, multipoint with regression analysis) and the testing of both pressurization and depressurization (averaging the results).

11.1.9.3 Any deviation(s) in the test procedure from standard practice and the specific reason for the deviation(s).

11.1.9.4 Description of any procedures or equipment, or both, used in order to ensure a single zone within the envelope.

11.1.10 Test equipment used.

11.1.10.1 Number of fans, gauges, and their location(s).

11.1.10.2 Manufacturer, model, and serial numbers of all equipment.

11.1.10.3 Date of last calibration and calibration certificates.

11.1.10.4 Results of field check procedures conducted on test equipment.

11.1.11 Test condition data.

11.1.11.1 General weather conditions (for example, rainy, cloudy, dry, etc.).

11.1.11.2 Ambient temperatures and inside building temperatures at beginning and end of test.

11.1.11.3 General wind speed data.

11.1.12 Measured test results in tabular form.

11.1.12.1 Start time of each test.

11.1.12.2 Measured airflows.

11.1.12.3 Measured pressure differentials.

11.1.12.4 End time of each test.

11.1.12.5 Results of measurements demonstrating single zone requirements were met.

11.1.12.6 Final results in units of the test specifications.

11.1.12.7 Calculated uncertainties.

11.1.12.8 For multipoint regression analysis, report the flow coefficient and exponent.

11.1.12.9 For repeated two-point test, report the exponent.

11.1.13 Conclusions.

11.1.13.1 Specified air leakage rate.

11.1.13.2 Test results using the units of the specified air leakage rate and associated uncertainty.

11.1.13.3 Determination of pass/fail.

11.1.13.4 Equivalent leakage area and normalized leakage area.

12. Precision and Bias

12.1 *Multi-Point Regression Tests*—The precision shall be calculated according to Eq A1.1 using an unweighted regression. The bias errors shall be calculated according to Eq A1.2. The overall measurement uncertainty shall be calculated using the following Eq 3.

$$\delta Q = Q\sqrt{\left(\frac{\delta Q_{bias}}{Q}\right)^2+\left(\frac{\delta Q_{prec,95\%}}{Q}\right)^2} \quad (3)$$

where:

δQ_{bias} = the result of Eq A1.2, and
$\delta Q_{prec,95\,\%}/Q$ = the relative precision error from the regression, at the 95 % confidence level.

12.2 *Repeated Single Point Tests*—The precision, bias, and overall measurement uncertainty of repeated single point tests shall be calculated according to A1.2 using Eq A1.2, Eq A1.3, and Eq A1.4, respectively. In Eq A1.2 and Eq A1.3, a pressure exponent n = 0.60 shall be used.

12.3 *Repeated Two-Point Tests*—The precision, bias, and overall measurement uncertainty of repeated two-point tests shall be calculated according to A1.3, Eq A1.5, Eq A1.6, and Eq A1.7, respectively.

12.4 *Reducing Precision Uncertainties*—recommended practice is to add data points to reduce precision uncertainties. Justification shall be given for removing data. Justification shall include a description of the problem with the data (for example, door or window opened, failed masking).

NOTE 9—Distance from the regression line or mean may justify examination of the data conditions but does not constitute a valid justification for removal of data.

13. Keywords

13.1 air leakage; airtightness; envelope; fan pressure test; whole building pressure test

ANNEXES

(Mandatory Information)

A1. TEST CALCULATIONS

A1.1 *Multi-Point Regression Tests*:

A1.1.1 *Precision Using an Unweighted Regression*—Determine confidence limits for the derived values from the data used to determine Eq A3.1 using Annex A3. To obtain confidence limits of a combined pressurization and depressurization result, use the combined result (which is the simple average of the pressurization and depressurization values) plus and minus the quanitity calculated using Eq A1.1.

$$PE95(x_{combined}) = \left(\frac{1}{2}\right)\cdot sqrt\left(PE95(x_{depress})^2 + PE95(x_{press})^2\right) \quad (A1.1)$$

where:

$PE95_{(x_{depress})}$ = half the width of the 95 % confidence interval (from Eq A1.1) in the depressurization result, and
$PE95_{(x_{press})}$ = half the width of the 95 % confidence interval (from Eq A1.1) in the pressurization result.

A1.1.2 *Bias Errors*—The bias for $\bar{Q}_{env}$, is given by Eq A1.2.

A1.2 *Repeated Single Point Tests*:

A1.2.1 The precision, bias, and overall measurement uncertainty of repeated single point tests shall be calculated according to Eq A1.2, Eq A1.3 and Eq A1.4, respectively. In Eq A1.2 and Eq A1.3, a pressure exponent n = 0.60 shall be used.

A1.2.1.1 The precision index for $\bar{Q}_{env}$, is given by:

$$\frac{\delta Q_{envprec}}{\bar{Q}_{env}} = \sqrt{\frac{\delta^2 Q_{precision}}{Q_{fan}^2}+n^2\,\frac{\delta^2 P_{precision}}{P_1^2}} \quad (A1.2)$$

where:

Q_{fan} = flow rate through the fan, m^3/s (ft^3/min),
P_1 = average pressure, $\bar{P}_{sta}$, at the primary pressure station, Pa (in. H_2O),
$\delta Q_{precision}$ = precision index of the average of the measured flow rate, m^3/s (ft^3/min), and
$\delta P_{precision}$ = precision index of the average of the measured pressure differential across the building envelope, Pa (in. H_2O).

A1.2.1.2 The bias for $\bar{Q}_{env}$, is given by:

$$\frac{\delta Q_{biasenv}}{\bar{Q}_{env}} = \sqrt{\frac{\delta^2 Q_{bias}}{Q_{fan}^2}+n^2\,\frac{\delta^2 P_{bias}}{P_1^2}} \quad (A1.3)$$