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Standard Test Method for Determining Air Leakage Rate by Fan Pressurization[1]

This standard is issued under the fixed designation E779; 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

1.1This test method covers a standardized technique for measuring air-leakage rates through a building envelope under controlled pressurization and de-pressurization.

1.2This test method is applicable to small temperature differentials and low-wind pressure conditions. For tests conducted in the field, it must be recognized that field conditions may be less than ideal. Nevertheless, strong winds and large indoor-outdoor temperature differentials should be avoided.

1.3This test method is intended to produce a measure of air tightness of a building envelope. This test method does not measure air leakage rates under normal conditions of weather and building operation. To measure air-change rate directly, use the tracer gas dilution method (see Test Method E1258).

1.4This test method is intended for the measurement of the airtightness of building envelopes of single-zone buildings. For the purpose of this test method, many multi-zone buildings can be treated as single-zone buildings by opening interior doors or by inducing equal pressures in adjacent zones.

1.5

1.1 This test method measures air-leakage rates through a building envelope under controlled pressurization and de-pressurization.

1.2 This test method is applicable to small temperature differentials and low-wind pressure differential, therefore strong winds and large indoor-outdoor temperature differentials shall be avoided.

1.3 This test method is intended to quantify the air tightness of a building envelope. This test method does not measure air change rate or air leakage rate under normal weather conditions and building operation.

NOTE 1—See Test Method E741 to directly measure air-change rates using the tracer gas dilution method

1.4 This test method is intended to be used for measuring the air tightness of building envelopes of single-zone buildings. For the purpose of this test method, many multi-zone buildings can be treated as single-zone buildings by opening interior doors or by inducing equal pressures in adjacent zones.

1.5 Only metric SI units of measurement are used in this standard. If a value for measurement is followed by a value in other units in parentheses, the second value may be approximate. The first stated value is the requirement.

1.6 *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 and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements see Section 7.

2. Referenced Documents

2.1 *ASTM Standards:* *ASTM Standards:*[2]

E631 Terminology of Building Constructions

E741 Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution

E1258 Test Method for Airflow Calibration of Fan Pressurization Devices

3. Terminology

3.1

[1] This test method is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.41 on Air Leakage and Ventilation.

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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.

3.1 For definitions of terms used in this test method, refer to Terminology E631.

3.2 *Definitions of Terms Specific to This Standard:*

~~3.1.1~~.

3.2.1 *air-change rate*, *n*~~—air-leakage rate in volume units/h divided by the building space volume with identical volume units, normally expressed as air changes/h, ACT~~.

~~3.1.2~~—*air-leakage rate in volume units/h divided by the building space volume with identical volume units, normally expressed as air changes/h, ACH.*

3.2.2 *air-leakage*, *n*—the movement/flow of air through the building envelope, which is driven by either or both positive (infiltration) and negative (exfiltration) pressure differences across the envelope.

3.2.3 *air-leakage graph*, *n*—the graph that shows the relationship of measured airflow rates to the corresponding measured pressure differences, usually plotted on a log-log scale.

~~3.1.3~~3.2.4 *air-leakage rate*, *n*~~—the volume of air movement/unit time across the building envelope.~~

~~3.1.3.1*Discussion*—This movement includes flow through joints, cracks, and porous surfaces, or a combination thereof. The driving force for such an air leakage, in service can be either mechanical pressurization and de-pressurization, natural wind pressures, or air temperature differentials between the building interior and the outdoors, or a combination thereof.~~

~~3.1.4~~—*the volume of air movement/unit time across the building envelope including airflow through joints, cracks, and porous surfaces, or a combination thereof driven by mechanical pressurization and de-pressurization, natural wind pressures, or air temperature differentials between the building interior and the outdoors, or a combination thereof.*

3.2.5 *building envelope*, *n*~~—the boundary or barrier separating the interior volume of a building from the outside environment.~~

~~3.1.4.1*Discussion*—For the purpose of this test method, the interior volume is the deliberately conditioned space within a building, generally not including attics, basements, and attached structures, for example, garages, unless such spaces are connected to the heating and air conditioning system, such as a crawl space plenum.~~

~~3.1.5~~—*the boundary or barrier separating different environmental conditions within a building and from the outside environment.*

3.2.6 *effective leakage area*, *n*—the area of a hole, with a discharge coefficient of 1.0, which, with a 4 Pa pressure difference, leaks the same as the building, also known as the sum of the unintentional openings in the structure

3.2.7 *height, building*, *n*—the vertical distance from grade plane to the average height of the highest ceiling surface.

3.2.8 *interior volume*, *n*—conditioned space within a building, generally not including attics and attached structures, for example, garages, unless such spaces are connected to the heating and air conditioning system, such as a crawl space plenum.

3.2.9 *single zone*, *n*—a space in which the pressure differences between any two places, differ by no more than 5 % of the inside to outside pressure difference.

~~3.1.5.1*Discussion*—A~~difference including multi-room space that is interconnected within itself with door-sized openings through any partitions or floors ~~is likely to satisfy this criterion if~~where the fan airflow rate is less than 3 m^3/s 6 × 10/s (6 × 10^{3} ft^3/min).

~~3.1.6~~

3.2.10 *test pressure difference*, *n*—the measured pressure difference across the building envelope, expressed in Pascals (in. of water or pounds-force/ft^2 or in. of mercury).

~~3.2~~

3.3 *Symbols and Units*—See Table 1.

4. Summary of Test Method

4.1 This test method consists of mechanical pressurization or de-pressurization of a building and measurements of the resulting airflow rates at given indoor-outdoor static pressure differences. From the relationship between the airflow rates and pressure differences, the air leakage characteristics of a building envelope can be evaluated. are determined.

TABLE 1 Symbols and Units

Symbol	Quantity	Unit
E	Elevation above sea level	m [ft]
Q	Measured airflow rate	m^3/s [cfm]
Q_o	Air leakage rate	m^3/s [cfm]
C	Air leakage coefficient	m^3/(s · Pa^n) [cfm/Pa^n]
ρ	Air density	kg/m^3[lb/ft^3]
T	Temperature	° C [°F]
n	Pressure exponent	. . .
P	Pressure	Pa [lb/ft^2]
dP	Induced pressure difference	Pa [lb/ft^2]
dP_r	Reference pressure difference	Pa [lb/ft^2]
μ	Dynamic air viscosity	kg/(m·s) [lb/(ft·h)]
A	Area	m^2[ft^2]

5. Significance and Use

5.1 Air leakage accounts for a significant portion of the thermal space conditioning load. In addition, it ~~can affect~~ affects occupant comfort and indoor air quality.

5.2 In most commercial or industrial buildings, outdoor air ~~often~~ is often introduced by design; however, air leakage ~~can be~~ is a significant addition to the designed outdoor airflow. In most residential buildings, indoor-outdoor air exchange is attributable primarily to air leakage through cracks and construction joints and ~~can be~~ is induced by pressure differences due to temperature differences, wind, operation of auxiliary ~~fans, for~~fans (for example, kitchen and bathroom exhausts), and the operation of combustion equipment in the building.

5.3 The fan-pressurization method is simpler than tracer gas measurements and is intended to characterize the air tightness of the building envelope. It ~~can be~~ is used to compare the relative air tightness of several similar buildings~~,~~ to identify the leakage sources and rates of leakage from different components of the same building envelope, and to determine the air leakage reduction for individual retrofit measures applied incrementally to an existing building, and to determine ventilation rates when combined with weather and leak location information.

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 ~~is~~shall be permitted.

6.2 *Major Components*:

6.2.1 *Air-Moving Equipment*~~—A fan,~~ —Fan, blower, HVAC air movement component or blower door assembly that is capable of moving air into and out of the conditioned space at required flow rates under a range of test pressure differences. The system shall provide constant airflow at each incremental pressure difference at fixed pressure for the period required to obtain readings of airflow rate. ~~Where applicable, the HVAC system of the building may be used in place of the fan or blower.~~

6.2.2 *Pressure-Measuring Device*~~—A manometer or pressure indicator to measure pressure difference with an accuracy of ±5% of measured pressure.~~ —Manometer or pressure indicator to measure pressure difference with an accuracy of ± 5 % of the measured pressure or 0.25 Pa (0.001 in. H_2O), whichever is greater.

6.2.3 *Airflow Measuring System*~~—A device~~ —Device to measure airflow with an accuracy of ± 5 % of the measured flow. The airflow measuring system shall be calibrated in accordance with Test MethodE1258.

6.2.4 *Temperature-Measuring Device*~~—An instrument to measure temperature with an accuracy of ±1°C (2°F).~~

~~6.2.5*Wind Speed-Measuring Device (Optional)*—A device to give an accuracy within ±0.25 m/s (0.56 mph) at 2.5 m/s (5.6 mph). Perform wind speed measurements at a distance three to five building heights away from the buildings, where practical. List the height above ground at which wind speed is measured.~~ —Instrument to measure temperature with an accuracy of ± 1°C (2°F).

7. Hazards

7.1 *Eye Protection*—Glass ~~should not break~~ breakage at the building pressure differences normally applied to the test structure is uncommon: however, for added safety, adequate precautions, such as the use of eye protection ~~should~~shall be taken to protect the personnel.

7.2 *Safety Clothing*—Use safety equipment required for general field work, including safety shoes, and hard hats.

7.3 *Equipment Guards*—The air-moving equipment shall have a proper guard or cage to house the fan or blower and to prevent accidental access to any moving parts of the equipment.

7.4 *Noise Protection*~~—Make hearing protection available for personnel who must be close to the noise that may be generated by the fan.~~ —Exposure to the noise level generated by fans can be hazardous to the hearing of involved personnel and hearing protection is required.

7.5 *Debris and Fumes*—The blower or fan forces a large volume of air into or out of a building while in operation. ~~Exercise care~~ Care shall be exercised to not to damage plants, pets, occupants, or internal furnishings due to influx of cold or warm air. ~~Exercise similar cautions~~ Caution shall be exercised against sucking debris or exhaust gases from fireplaces and flues into the interior of the building. Active combustion devices ~~require a properly trained technician to shut them off or to determine the safety of~~shall be shut off or the safety determined of conducting the test by a properly trained technician before conducting the test.

8. Procedure

8.1 To create a single zone for this test procedure, all interconnecting ~~doors, except for closets, which should be closed,~~ doors in the conditioned space ~~should~~shall be ~~opened~~open such that a uniform pressure ~~will~~shall be maintained within the conditioned space to within ±10 % of the measured inside/outside pressure difference. ~~Verify this~~ This condition shall be verified by differential pressure measurements at the highest pressure used in the test. ~~Make these~~ These measurements shall be taken at the highest ceiling elevation and lowest ~~level~~ floor elevation of the building and on the windward and leeward sides.

8.2 HVAC balancing dampers and registers ~~should~~shall not be adjusted. Fireplace and other operable dampers ~~should~~shall be closed unless they are used to pass air to pressurize or de-pressurize the building.

~~8.3Make general~~ 8.3 General observations of the condition of the ~~building. Take notes on~~building shall be recorded, including appropriate observations of the windows, doors, opaque walls, roof, and floor.

8.4 ~~Measure and record the indoor and outdoor temperatures at the beginning and the end of the test so that their average values~~

can be estimated. If the product of the absolute value of the indoor/outdoor air temperature difference multiplied by the building height, gives a result greater than 200 m°C (1180 ft°F), do not perform the test, because the pressure difference induced by the stack effect is too large to allow accurate interpretation of the results.

8.5If the wind speed is to be part of the measurement record, use a wind-measuring device or obtain readings from a nearby weather bureau. Preferred test conditions are wind speed of 0 to 2 m/s (0 to 4 mph) and an outside temperature from 5 to 35°C (41 to 95°F).

8.6Connect the air duct or blower door assembly to the building envelope, using a window, door, or vent opening. Seal or tape openings to avoid leakage at these points.

8.7If a damper is used to control airflow, it should be in a fully closed position for the zero flow pressure measurements.

8.8*Measure and record the indoor and outdoor temperatures at the beginning and the end of the test and average the values. If the product of the absolute value of the indoor/outdoor air temperature difference multiplied by the building height, gives a result greater than 200 m °C (1180 ft °F), the test shall not be performed, because the pressure difference induced by the stack effect is too large to allow accurate interpretation of the results.*

8.5 Connect the air duct or blower door assembly to the building envelope, using a window, door, or vent opening. Seal or tape openings to avoid air leakage at these points.

8.6 If a damper is used to control airflow, it shall be in a fully closed position for the zero flow pressure measurements.

8.7 *Installing the Envelope Pressure Sensor(s)*—Install the pressure measuring device across the building envelope. It is good practice to use more than one location across the building envelope for pressure measurement, for example, one across each facade. —Install the pressure measuring device across the building envelope. Where possible, locate the pressure tap at the bottom of the leeward wall. When wind causes adverse pressure fluctuations it may be advantageous to average the pressures measured at multiple locations, for example, one across each facade. Fig. 1 illustrates preferred locations for exterior pressure measurement locations that avoid extremes of exterior pressures (at exterior corners). A good location avoids exterior corners and complex architectural features and should be close to the middle of the exterior wall. In addition, buildings more than three stories, or 7.5 m (25.5 ft), high shall have exterior pressures measured at more than one height on the exterior walls. The pressures from each location should be averaged, typically using a manifold. Average the pressures over at least a 10-s time period.

8.9Measure zero flow pressures with the fan opening blocked. These zero flow envelope pressures are measured before and after the flow measurements. These zero flow pressures are to be subtracted from the envelope pressures measured during pressurization and depressurization. illustrates preferred locations that avoid extremes of exterior pressures. A good location avoids exterior corners and should be close to the middle (horizontally) of the exterior wall. Beware of direct sunlight hitting pressure tubing, especially vertical sections.

8.8 Measure zero flow pressures with the fan opening blocked. These zero flow envelope pressures shall be measured before and after the flow measurements. The average over at least a 10-s interval shall be used. These zero flow pressures shall be subtracted from the envelope pressures measured during pressurization and depressurization.

NOTE1—Some 2—Some equipment may perform this step, or an equivalent step, automatically. Follow the manufacturer's instructions accordingly.

8.10The8.9 The range of the induced pressure difference shall be from 10 to 60 Pa (0.04 to 0.24 in. H_2O), depending on the capacity of the air-handlingair-moving equipment. Because the capacity of the air handling air-moving equipment, the tightnesslack of tightness in the building, and the weather conditions affect leakage measurements, the full range of the higher

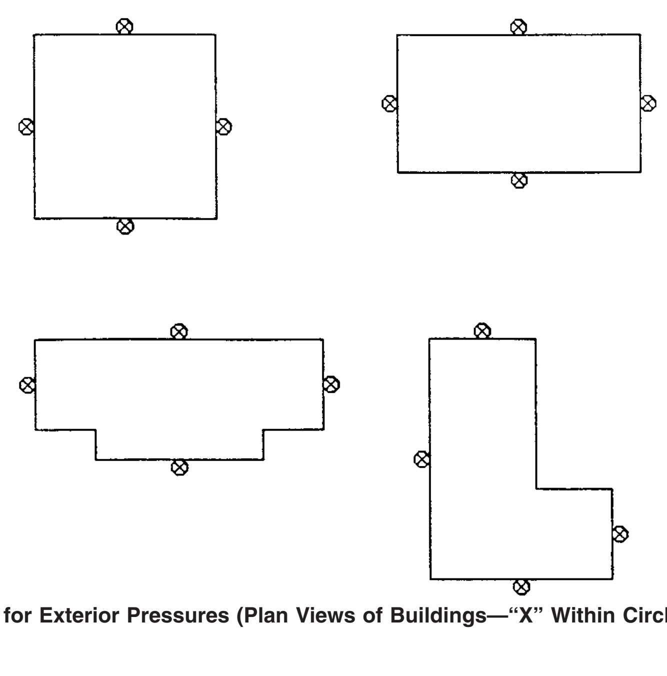

FIG. 1 Recommended Locations for Exterior Pressures (Plan Views of Buildings—"X" Within Circles Mark Pressure Tap Locations)

values may not be achievable. In such cases, substitute a partial range encompassing at least five data points.

NOTE ~~2—It~~ 3—It is advisable to check that the condition of the building envelope has not changed after each pressure reading, for example, that sealed openings have not become unsealed or that doors, windows, or dampers have not been forced open by the induced pressure.

~~8.11Use~~8.10 Use increments of 5 to 10 Pa (0.02 to 0.04 in. H_2O) for the full range of induced pressure differences.

~~8.12At~~8.11 At each pressure difference, measure the airflow rate and the pressure differences across the envelope. After the fan and instrumentation have stabilized, the average over at least a 10-s interval ~~should~~shall be used.

~~8.13For~~8.12 For each test, collect data for both pressurization and de-pressurization.

8.1~~4~~3 Determine the elevation of the measurement site, *E* (m or ft), above mean sea level within 100 m (330 ft).

9. Data Analysis and Calculations

9.1 ~~Unless the airflow measuring system gives volumetric flows at the pressure and the temperatures of the air flowing through the flowmeter during the test, these readings must be converted using information obtained from the manufacturer for the change in calibration with these parameters.~~ Unless the airflow measuring system gives volumetric flows at the barometric pressure and the temperatures of the air flowing through the flowmeter during the test, these readings shall be converted using information obtained from the manufacturer for the change in calibration with these parameters. The barometric pressure or air density, if used in the conversions, may be calculated using equations from Appendix X1.

9.2 Convert the readings of the airflow measuring system (corrected as in 9.1, if necessary) to volumetric air flows at the temperature and barometric ~~pressure, due to elevation changes only,~~pressure of the outside air for depressurization tests or of the inside air for pressurization tests (see Appendix X1~~). To convert the airflow rate to air leakage rate for depressurization, use the following equation:~~ , Eq X1.1 through X1.4 for determining indoor and outdoor air densities). To convert the airflow rate to air leakage rate for depressurization, use the following equation:

$$Q_o = Q\left(\frac{\rho_{in}}{\rho_{out}}\right) \quad (1)$$

ρout

where:

ρ_{in} = the indoor air density, in kg/m^3 (lb/ft^3), and

~~ρ~~ ρ_{out} = the outdoor air density, in kg/m^3 (lb/ft^3).

9.2.1 To convert the airflow rate to air leakage rate for pressurization, use the following equation:

(2) *Qo* = *Q*ρ*out*ρ *in*

9.3 Average the zero flow envelope pressures measured before and after the flow measurements. Subtract the average from the measured envelope pressures at each pressure station to determine the corrected envelope pressures.

9.4 Plot the measured air leakage against the corrected pressure differences on a log-log plot to complete the air leakage graph for both pressurization and de-pressurization (for an example, see Fig. 2).

9.5 Use the data to determine the air leakage coefficient, *C*, and pressure exponent, *n*, in Eq 3 separately for pressurization and depressurization:

$$Q = C(dP)^n \quad (3)$$

9.5.1 Use an unweighted log-linearized linear regression technique, where *Q*is the airflow rate, in m^3/s (ft^3~~/min), and *dP* is the differential pressure in Pa. In determining the fit of the above equation, the confidence intervals of the derived air leakage~~

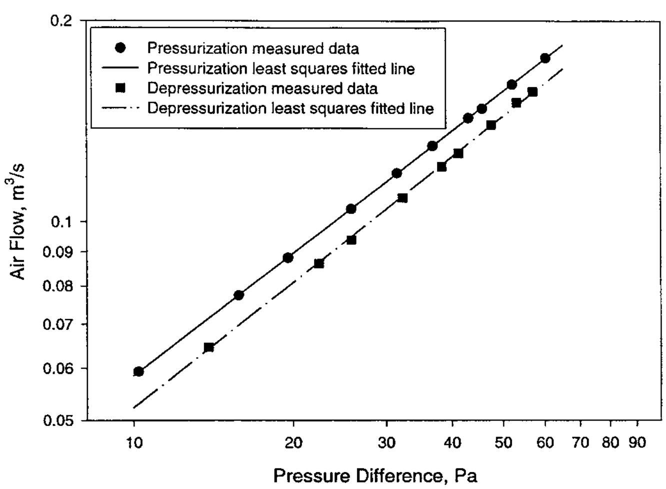

FIG. 2 Example Air Leakage Graph

~~coefficient C and pressure exponent n should be calculated. C and n shall be calculated separately for pressurization and depressurization. If the pressure exponent is less than 0.5 or greater than 1, then the test is invalid and should be repeated.~~ /min), and dP is the differential pressure in Pa. In determining the fit of the above equation, the confidence intervals of the derived air leakage coefficient C and pressure exponent n shall be calculated according to Appendix X1. C and n shall be calculated separately for pressurization and depressurization. If the pressure exponent is less than 0.5 or greater than 1, then the test is invalid and shall be repeated.

NOTE 4—Check the following before repeating the test:
(1) Equipment for proper calibration,
(2) Weather conditions against the temperature and pressure used in the calculations,
(3) Connection of the pressurizing fan to the enclosure for leaks,
(4) Connection between sections of the building, and
(5) All windows, doors, and other potential building openings are closed, etc.

9.6 Correct the air leakage coefficient C to standard conditions ~~(20°C~~[20°C and sea level E = 0 m (68°F, E = 0 ~~ft))~~ft))] with Eq 4.

$$C_o = C\left(\frac{\mu}{\mu_o}\right)^{2n-1}\left(\frac{\rho}{\rho_o}\right)^{1-n} \quad (4)$$

where:
μ = the dynamic viscosity of air, kg/m·s (lb/ft/h), and
ρ = the air density, kg/m^3(lb/ft^3).

9.6.1 The unsubscripted quantities refer to the values under the conditions of the test (indoor air for pressurization and outdoor air for depressurization), and the subscripted quantities to the values under the standard reference conditions. Appendix X1 contains the appropriate tables and equations for the temperature and barometric pressure (elevation) variation of ρ and μ.

9.6.2 The leakage area A_L, in m^2, ~~can~~shall be calculated from the corrected air leakage coefficient and the pressure exponent using a reference pressure (dP_r) in Eq 5. Calculate the leakage areas separately for pressurization and depressurization:

$$A_L = C_o\left(\frac{\rho_o}{2}\right)^{\frac{1}{2}}(dP_r)^{\left(n-\frac{1}{2}\right)} \quad (5)$$

9.6.3 The conventional reference pressure is 4 Pa, but other values may be used if the value is included in the test report.

9.6.4 To obtain a single value for flow coefficient, pressure exponent, leakage area or flow at a particular pressure for use in other calculations, the average of the values obtained for pressurization and depressurization shall be used.

9.7 ~~Determine confidence limits for the derived values from the data used to determine Eq 3 using Appendix X2.~~ Determine confidence limits for the derived values from the data used to determine Eq 3 using Annex A1. To obtain the 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 quantity calculated using equation Eq 6.

(6) $PE95(xcombined) = (12) * sqrt(PE95(xdepress)2 + PE95(xpress)2)$

where:
$PE95(x_{depress})$ = half the width of the 95 % confidence interval (from 9.7) in the depressurization result, and
$PE95(x_{press})$ = half the width of the 95 % confidence interval (from 9.7) in the pressurization result.

10. Report

10.1 Report the following information:

10.1.1 Building description, including location, address (street, city, state or province, zip or postal code, country, and elevation [above mean sea level in m (ft)].

10.1.2 Construction, including date built (estimate if unknown), floor areas for conditioned space, attic, basement, and crawl space, and volumes for conditioned spaces, attic, basement, and crawl space.

10.1.3 Condition of openings in building envelope including:

10.1.3.1 Doors, closed, locked or unlocked;

10.1.3.2 Windows, closed, latched or unlatched;

10.1.3.3 Ventilation openings, dampers closed or open;

10.1.3.4 Chimneys, dampers closed or open; and a

10.1.3.5 Statement whether the test zone is interconnected with at least door-sized openings. If not, the results of pressure measurements between portions of the zone.

10.1.4 HVAC system, including the location and sizes of ducts that penetrate the test zone envelope.

10.2 Procedure, including the test equipment used (manufacturer, model, serial number), and calibration records of all measuring equipment.

10.3 Measurement data, including:

10.3.1 Fan pressurization measurements (inside-outside zero flow building pressure differences); inside and outside temperature