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Standard BSR/RESNET 380-20xx PDS-1

Standard for Testing Air Leakage of Building Enclosures, Air Leakage of Heating and Cooling Air Distribution Systems, and Airflow of Mechanical Ventilation Systems

1. Purpose

1.1. The provisions of this document are intended to establish national standards for testing the air leakage of enclosures and heating and cooling air distribution systems, and the airflow of mechanical ventilation systems. These standards are intended for use by home energy raters, energy auditors, or code officials to evaluate the performance of residential buildings.

2. Scope

2.1. This standard defines procedures for measuring the air leakage of building enclosures, the air leakage of heating and cooling air distribution systems, and the airflow of mechanical ventilation systems.

This standard is applicable to all single family dwelling units.

The procedure for measuring the air leakage of building enclosures is also applicable to dwelling units in multifamily buildings three stories or less in height above ground.

The procedure for measuring the air leakage of heating and cooling air distribution systems is also applicable to dwelling units in multifamily buildings three stories or less in height above ground, where each dwelling unit has its own duct system separate from other dwelling units.

The procedure for measuring the airflow of mechanical ventilation systems is also applicable to dwelling units in multifamily buildings three stories or less in height above ground, where each dwelling unit has its own ventilation system separate from other dwelling units.

3. Procedure for Measuring Air Leakage of Building Enclosure

3.1. Equipment Needed

- 3.1.1.** Air-Moving Fan. A fan that is capable of moving air into or out of the building to achieve a range of pressure differences.
- 3.1.2.** Manometer. A device that can measure pressure difference with an accuracy equal to or better than $\pm 5\%$ or 0.25 Pa (0.001 in. H₂O), whichever is greater.

- 3.1.3. Airflow Meter. A device to measure volumetric airflow with an accuracy equal to or better than $\pm 5\%$ of the measured flow.
- 3.1.4. Thermometer. An instrument to measure air temperature with an accuracy of $\pm 1^\circ\text{C}$ (2°F).
- 3.1.5. Blower Door. A device that combines an Air-Moving Fan as defined in Section 3.1.1 and an Airflow Meter as defined in Section 3.1.3.

3.2. Procedure to Prepare the Building for Testing

Any abnormal conditions shall be recorded on the test report.

- 3.2.1. **Fenestration.** Doors and windows that are part of the conditioned space boundary shall be closed and latched.
- 3.2.2. **Attached garages.** If attached garage is not within the pressure boundary of the house, exterior garage doors shall be opened. If attached garage is within the pressure boundary of the home, exterior garage doors shall be closed. In either case, windows in the attached garage shall be closed. The Air-Moving Fan shall only be permitted to be installed between the house and the garage if the garage is not within the pressure boundary of the house.
- 3.2.3. **Crawlspaces.** If a crawlspace is inside the conditioned space boundary, interior access doors and hatches between the house and the crawlspace shall be opened and exterior crawlspace access doors, vents, and hatches shall be closed. If a crawlspace is outside the conditioned space boundary, interior access doors and hatches shall be closed and crawlspace vents shall be left in their as-found position and their position shall be recorded on the test report.
- 3.2.4. **Attics.** If an attic is inside the conditioned space boundary, interior access doors and hatches between the house and the conditioned attic shall be opened and attic exterior access doors and windows shall be closed. If an attic is outside the conditioned space boundary, interior access doors and hatches shall be closed. In addition, exterior access doors, dampers, or vents shall be left in their as-found position and their position shall be recorded on the test report.
- 3.2.5. **Interior doors.** All doors between rooms inside the conditioned space boundary shall be opened.
- 3.2.6. **Chimney dampers and combustion-air inlets on solid fuel appliances.** Chimney dampers and combustion-air inlets on solid fuel appliances shall be closed. Precautions shall be taken to prevent ashes or soot from entering the house during testing.
- 3.2.7. **Combustion appliance flue gas vents.** Combustion appliance flue gas vents shall be left in their as-found position.
- 3.2.8. **Fans.** Any fan or appliance capable of inducing airflow across the building enclosure shall be turned off including, but not limited to, clothes dryers, attic fans, kitchen and bathroom exhaust fans, air handlers, ventilation fans used in

a whole-house mechanical ventilation system (e.g., a system intended to meet ASHRAE Standard 62.2), and crawlspace and attic ventilation fans.

3.2.9. Dampers

3.2.9.1. Non-motorized dampers (e.g., pressure-activated operable dampers, fixed dampers) that connect the conditioned space to the exterior or to unconditioned spaces shall be left in their as-found positions. For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan shall be left in its as-found position.

3.2.9.2. Motorized dampers that connect the conditioned space to the exterior or to unconditioned spaces shall be placed in their closed positions and shall not be further sealed.

3.2.10. Non-dampened ventilation openings

3.2.10.1. Non-dampened ventilation openings of intermittently operating local exhaust ventilation systems (e.g., bath fan, kitchen range fan) that connect the conditioned space to the exterior or to unconditioned spaces shall be left open.

3.2.10.2. Non-dampened ventilation openings of intermittently operating whole-house ventilation systems, including HVAC fan-integrated outdoor air inlets, that connect the conditioned space to the exterior or to unconditioned spaces shall not be sealed.

3.2.10.3. Non-dampened ventilation openings of continuously operating whole-house ventilation systems that connect the conditioned space to the exterior or to unconditioned spaces shall be sealed, preferably at the exterior of the enclosure.

3.2.11. Whole-building fan louvers/shutters. Whole-building fan louvers and shutters shall be closed. In addition, if there is a seasonal cover present, it shall be installed.

3.2.12. Evaporative coolers. The opening to the exterior of evaporative coolers shall be placed in its off position. In addition, if there is a seasonal cover present, it shall be installed.

3.2.13. Operable window trickle-vents and through-the-wall vents. Operable window trickle-vents and through-the-wall vents shall be closed.

3.2.14. Supply registers and return grilles. Supply registers and return grilles shall be left in their as-found position and left uncovered.

3.2.15. Plumbing drains with p-traps. Plumbing drains with empty p-traps shall be sealed or filled with water.

3.2.16. Vented combustion appliances. Vented combustion appliances shall remain off or in "pilot only" mode for the duration of the test.

3.3. Procedure to Install the Test Apparatus and Prepare for Air Leakage Test

- 3.3.1. The Blower Door shall be installed in an exterior doorway or window that has an unrestricted air pathway into the building and no obstructions to airflow within five feet of the fan inlet and two feet of the fan outlet. The opening that is chosen shall be noted on the test report. If possible, the system shall not be installed in a doorway or window exposed to wind. It is permissible to use a doorway or window between the conditioned space and an unconditioned space as long as the unconditioned space has an unrestricted air pathway to the outdoors and all operable exterior windows and doors of the unconditioned space are opened to the outdoors. For multifamily dwelling units, if the main entry door is in an interior hallway then the hallway shall be well connected to outside through open windows or doors, or an exterior window or door (e.g., leading to a deck or patio) shall be used.
- 3.3.2. Tubing shall be installed to measure the difference in pressure between the enclosure and the outdoors in accordance with manufacturer's instructions. The tubing, especially vertical sections, shall be positioned out of direct sunlight.
- 3.3.3. The indoor and outdoor temperatures shall be measured using the Thermometer and recorded. Observations of general weather conditions shall be recorded.
- 3.3.4. The altitude of the building site above sea level shall be recorded with an accuracy of 2,000 feet (750m).
- 3.3.5. The model and serial number(s) of all measurement equipment shall be recorded.
- 3.3.6. If the results of the test will be reported as Air Changes Per Hour at 50 Pa (0.2 in. H₂O) (*ACH50*), the volume of the house shall be recorded.
- 3.3.7. If the results of the test will be reported as Specific Leakage Area (*SLA*), the floor area of the house shall be recorded.

3.4. Procedure to Conduct Air Leakage Test. The leakage of the enclosure shall be measured using either the One-Point Air Leakage Test in Section 3.4.1 or the Multi-Point Air Leakage Test in Section 3.4.2.

3.4.1. One-Point Air Leakage Test

- 3.4.1.1. With the Air-Moving Fan turned off and sealed, the pressure difference across the enclosure shall be recorded using the Manometer, with the outside as the reference. The measurement shall represent the average value over at least a 10 second period and shall be defined as the Pre-Test Baseline Building Pressure.
- 3.4.1.2. The Air-Moving Fan shall be unsealed, turned on, and adjusted to create an induced enclosure pressure difference of 50 Pa (0.2 in. H₂O), defined as the induced enclosure pressure minus the Pre-Test Baseline Building Pressure. Note that this value is permitted to be positive or negative, which will be dependent upon whether the enclosure is pressurized or depressurized. An indication of whether

the Air-Moving Fan pressurized or depressurized the house shall be recorded.

If a 50 Pa (0.2 in. H₂O) induced enclosure pressure difference can be achieved, then the average value of the induced enclosure pressure difference and the airflow at 50 Pa (0.2 in. H₂O), measured over at least a 10 second period, shall be recorded.

If a 50 Pa (0.2 in. H₂O) induced enclosure pressure difference cannot be achieved, then additional Air-Moving Fans shall be used or the highest induced enclosure pressure difference (dP_{high}) and airflow (Q_{high}) that was achieved with the equipment available, measured over at least a 10 second period, shall be recorded. A minimum of 15 Pa (0.06 in. H₂O) must be induced across the enclosure for the test to be valid.

3.4.1.3. The Air-Moving Fan shall be turned off and the home returned to its as-found condition.

3.4.1.4. If an induced enclosure pressure difference of 50 Pa (0.2 in. H₂O) was not achieved in Section 3.4.1.2, then the recorded airflow (Q_{high}) shall be converted to a nominal airflow at 50 Pa (0.2 in. H₂O) using Equation 1. Alternately, a Manometer that is equipped to automatically make the conversion to *CFM50* or *CMS50* is permitted to be used.

$$CFM50 \left(\frac{ft^3}{min} \right) = Q_{high} \left(\frac{ft^3}{min} \right) \left(\frac{50}{dP_{high}} \right)^{0.65} \quad (1a)$$

$$CMS50 \left(\frac{m^3}{s} \right) = Q_{high} \left(\frac{m^3}{s} \right) \left(\frac{50}{dP_{high}} \right)^{0.65} \quad (1b)$$

3.4.1.5. The airflow at 50 Pa shall be corrected for altitude and temperature to determine the corrected airflow at 50 Pa using Equation 2:

$$Corrected\ CFM50 = CFM50 \times ACF \times TCF \quad (2a)$$

Where:

ACF = Altitude Correction Factor = $1 + 0.000006 \times$ Altitude in feet, using the altitude measured in Section 3.3.4.

TCF = Temperature Correction Factor = Value selected from Table 1a for pressurization and Table 1b for depressurization, using the indoor and outdoor temperature measured in Section 3.3.3. Alternatively, a manufacturer's temperature correction is permitted to be used.

$$Corrected\ CMS50 = CMS50 \times ACF \times TCF \quad (2b)$$

Where:

$ACF = \text{Altitude Correction Factor} = 1 + 0.000003 \times \text{Altitude in meters}$, using the altitude measured in Section 3.3.4.

$TCF = \text{Temperature Correction Factor} = \text{Value selected from Table 1a for pressurization and Table 1b for depressurization}$, using indoor and outdoor temperature measured in Section 3.3.3. Alternatively, a manufacturer's temperature correction is permitted to be used.

**Table 1a. Temperature Correction Factors for Pressurization Testing,
Calculated According to ASTM E779-10**

Outside Temp (F)	Inside Temperature (F)								
	50	55	60	65	70	75	80	85	90
-20	1.16	1.17	1.18	1.19	1.20	1.22	1.23	1.24	1.25
-10	1.13	1.14	1.16	1.17	1.18	1.19	1.20	1.21	1.22
0	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.20
10	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17
20	1.06	1.07	1.08	1.09	1.10	1.11	1.13	1.14	1.15
30	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12
40	1.02	1.03	1.04	1.05	1.06	1.07	1.08	1.09	1.10
50	1.00	1.01	1.02	1.03	1.04	1.05	1.06	1.07	1.08
60	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.05	1.06
70	0.96	0.97	0.98	0.99	1.00	1.01	1.02	1.03	1.04
80	0.94	0.95	0.96	0.97	0.98	0.99	1.00	1.01	1.02
90	0.93	0.94	0.95	0.95	0.96	0.97	0.98	0.99	1.00
100	0.91	0.92	0.93	0.94	0.95	0.96	0.96	0.97	0.98
110	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.96

Outside Temp (C)	Inside Temperature (C)								
	12	14	16	18	20	22	24	26	28
-20	1.13	1.13	1.14	1.15	1.16	1.17	1.17	1.18	1.19
-15	1.10	1.11	1.12	1.13	1.14	1.14	1.15	1.16	1.17
-10	1.08	1.09	1.10	1.11	1.11	1.12	1.13	1.14	1.14

-5	1.06	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.12
0	1.04	1.05	1.06	1.07	1.07	1.08	1.09	1.10	1.10
5	1.03	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.08
10	1.01	1.01	1.02	1.03	1.04	1.04	1.05	1.06	1.06
15	0.99	1.00	1.00	1.01	1.02	1.02	1.03	1.04	1.05
20	0.97	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.03
25	0.96	0.96	0.97	0.98	0.98	0.99	1.00	1.00	1.01
30	0.94	0.95	0.95	0.96	0.97	0.97	0.98	0.99	0.99
35	0.93	0.93	0.94	0.94	0.95	0.96	0.96	0.97	0.98

**Table 1b. Temperature Correction Factors for Depressurization Testing,
Calculated According to ASTM E779-10**

Outside Temp (F)	Inside Temperature (F)								
	50	55	60	65	70	75	80	85	90
-20	0.86	0.85	0.85	0.84	0.83	0.82	0.81	0.81	0.80
-10	0.88	0.87	0.87	0.86	0.85	0.84	0.83	0.83	0.82
0	0.90	0.89	0.88	0.88	0.87	0.86	0.85	0.84	0.84
10	0.92	0.91	0.90	0.90	0.89	0.88	0.87	0.86	0.85
20	0.94	0.93	0.92	0.91	0.91	0.90	0.89	0.88	0.87
30	0.96	0.95	0.94	0.93	0.92	0.92	0.91	0.90	0.89
40	0.98	0.97	0.96	0.95	0.94	0.93	0.93	0.92	0.91
50	1.00	0.99	0.98	0.97	0.96	0.95	0.94	0.94	0.93
60	1.02	1.01	1.00	0.99	0.98	0.97	0.96	0.95	0.95
70	1.04	1.03	1.02	1.01	1.00	0.99	0.98	0.97	0.96
80	1.06	1.05	1.04	1.03	1.02	1.01	1.00	0.99	0.98
90	1.08	1.07	1.06	1.05	1.04	1.03	1.02	1.01	1.00
100	1.10	1.09	1.08	1.07	1.06	1.05	1.04	1.03	1.02
110	1.12	1.11	1.10	1.09	1.08	1.07	1.06	1.05	1.04

Outside Temp (C)	Inside Temperature (C)								
	12	14	16	18	20	22	24	26	28
-20	0.89	0.88	0.88	0.87	0.86	0.86	0.85	0.85	0.84
-15	0.91	0.90	0.89	0.89	0.88	0.87	0.87	0.86	0.86
-10	0.92	0.92	0.91	0.90	0.90	0.89	0.89	0.88	0.87
-5	0.94	0.93	0.93	0.92	0.91	0.91	0.90	0.90	0.89
0	0.96	0.95	0.94	0.94	0.93	0.93	0.92	0.91	0.91
5	0.98	0.97	0.96	0.96	0.95	0.94	0.94	0.93	0.92
10	0.99	0.99	0.98	0.97	0.97	0.96	0.95	0.95	0.94
15	1.01	1.00	1.00	0.99	0.98	0.98	0.97	0.96	0.96
20	1.03	1.02	1.01	1.01	1.00	0.99	0.99	0.98	0.97
25	1.05	1.04	1.03	1.02	1.02	1.01	1.00	1.00	0.99
30	1.06	1.06	1.05	1.04	1.03	1.03	1.02	1.01	1.01
35	1.08	1.07	1.07	1.06	1.05	1.04	1.04	1.03	1.02

3.4.1.6. The Effective Leakage Area (*ELA*) shall be calculated using Equation 3:

$$ELA(in^2) = \frac{Corrected\ CFM50}{18.2} \quad (3a)$$

$$ELA(m^2) = \frac{Corrected\ CMS50}{9.13} \quad (3b)$$

3.4.2. Multi-Point Air Leakage Test

3.4.2.1. With the Air-Moving Fan turned off and sealed, the pressure difference across the enclosure shall be recorded using the Manometer, with the outside as the reference. The measurement shall represent the average value over at least a 10 second period and shall be defined as the Pre-Test Baseline Building Pressure.

3.4.2.2. The Air-Moving Fan shall be unsealed, turned on, and adjusted to create a range of induced enclosure pressure differences at approximately equally-spaced pressure stations between 10 Pa (0.04 in. H₂O) and either 60 Pa (0.24 in. H₂O) or the highest achievable pressure difference up to 60 Pa. The induced enclosure pressure difference is defined as the induced enclosure pressure minus the Pre-Test Baseline Building Pressure. Note that this value is permitted to be positive or negative, which will be dependent upon whether the enclosure is pressurized or depressurized. An indication of whether

the Air-Moving Fan pressurized or depressurized the house shall be recorded.

At each pressure station, the average value of the induced enclosure pressure difference, the airflow, and the temperature, measured over at least a 10 second period, shall be recorded. The highest induced enclosure pressure difference shall be at least 25 Pa (0.1 in. H₂O). If 25 Pa (0.1 in. H₂O) cannot be achieved, the One-Point Air Leakage Test in Section 3.4.1 shall be used.

- 3.4.2.3.** The Air-Moving Fan shall be turned off and the home returned to its as-found condition.
- 3.4.2.4.** The airflow at each pressure station shall be corrected for altitude and temperature to determine the corrected airflow using Equation 2.
- 3.4.2.5.** The corrected airflow (Q) and the induced enclosure pressure difference measured at each pressure station (dP) shall be used in a log-linearized regression of the form $Q = C(dP)^n$ (e.g., using the procedures in ASTM E779-10, Section 9 and Annex A.1) to calculate C and n .
- 3.4.2.6.** The Effective Leakage Area (ELA) shall be calculated using Equation 4:

$$ELA(in^2) = C \left(\frac{ft^3}{minPa^n} \right) \times 0.567 \times 4^{(n-0.5)} \quad (4a)$$

$$ELA(m^2) = C \left(\frac{m^3}{sPa^n} \right) \times 0.775 \times 4^{(n-0.5)} \quad (4b)$$

Where C and n are the values determined in Section 3.4.2.5.

3.5. Procedure to Apply Results of Enclosure Air Leakage Test

- 3.5.1.** If the results of the building enclosure air leakage test are to be used for the purpose of calculating the expected energy savings from a retrofit, conducting an energy audit, or assessing the relative enclosure air leakage of a group of buildings, then the corrected airflow determined in Section 3.4.1.5 or Section 3.4.2.4 shall be used.
- 3.5.2.** If the results of the building enclosure air leakage test are to be used for conducting a home energy rating or assessing compliance with a building enclosure leakage limit (e.g., defined by code or by an energy efficiency program), then the corrected airflow determined using a one-point test shall be adjusted using Equation 5a or 5b and the corrected airflow determined using a multi-point test shall be adjusted using Equation 6a or 6b.

$$Adjusted\ CFM50 = 1.22 \times Corrected\ CFM50 \quad (5a)$$

$$Adjusted\ CMS50 = 1.22 \times Corrected\ CMS50 \quad (5b)$$

$$\text{Adjusted CFM50} = 1.1 \times \text{Corrected CFM50} \quad (6a)$$

$$\text{Adjusted CMS50} = 1.1 \times \text{Corrected CMS50} \quad (6b)$$

The *ELA* determined in Section 3.4.1.6 for a One-Point Air Leakage Test shall be adjusted using Equation 7a or the *ELA* determined for a Multi-Point Air Leakage Test in Section 3.4.2.6 shall be adjusted using Equation 7b.

$$\text{Adjusted ELA} = 1.22 \times \text{ELA} \quad (7a)$$

$$\text{Adjusted ELA} = 1.1 \times \text{ELA} \quad (7b)$$

3.5.3. If the results of the building enclosure leakage test are to be converted to Air Changes Per Hour at 50 Pa (0.2 in. H₂O) (*ACH50*), Specific Leakage Area (*SLA*), or Normalized Leakage Area (*NLA*), then Equations 8 through 10 shall be used, as applicable, where *CFM50*, *CMS50*, and *ELA* have been adjusted in section 3.5.2, if necessary.

$$\text{ACH50} = \text{CFM50} \times 60 / \text{Building Volume in cubic feet} \quad (8a)$$

$$\text{ACH50} = \text{CMS50} \times 60 / \text{Building Volume in cubic meters} \quad (8b)$$

$$\text{SLA} = 0.00694 \times \text{ELA in in}^2 / \text{Building Floor Area in square feet} \quad (9a)$$

$$\text{SLA} = 10.764 \times \text{ELA in m}^2 / \text{Building Floor Area in square meters} \quad (9b)$$

$$\text{NLA} = \text{SLA} \times (S)^{0.4}, \text{ where } S \text{ is the number of stories above grade} \quad (10)$$

4. Procedure for Measuring Leakage of Duct Systems

In addition to the test procedures in this section, test method A from ASTM E1554-13 is approved for use provided that the building and duct system preparation procedures in Section 4.2 of this standard are followed.

For multifamily buildings where each unit has its own duct system, each unit shall be tested individually. The leakage to outside test shall be performed using a Blower Door in the main entry to the unit to pressurize the individual unit with reference to outside. If the main entry door is in an interior hallway then the hallway shall be well connected to outside through open windows or doors, or an exterior window or door (such as to deck or patio) shall be used. Only the ducts in the unit under test are tested.

4.1. Equipment Needed

4.1.1. Air-Moving Fan. A fan that is capable of moving air into or out of the duct system to achieve a pressure difference of 25 Pa (0.1 in. H₂O).

4.1.2. Manometer. A device that can measure pressure difference with an accuracy of $\pm 5\%$ of the measured pressure or 0.25 Pa (0.001 in. H₂O), whichever is greater.

- 4.1.3. Flow Meter. A device to measure volumetric airflow with an accuracy equal to or better than $\pm 5\%$ of the measured flow.
- 4.1.4. Thermometer. An instrument to measure air temperature with an accuracy of $\pm 1^\circ\text{C}$ ($\pm 2^\circ\text{F}$).
- 4.1.5. Duct Leakage Tester. A device that combines an Air-Moving Fan as defined in Section 4.1.1 and a Flow Meter as defined in Section 4.1.3.

4.2. Procedure to Prepare the Building and the Duct System for Testing

- 4.2.1. The HVAC system controls shall be adjusted so that the air handler fan does not turn on during the test.
- 4.2.2. Any fans that could change the pressure in either the conditioned space or any spaces containing ducts or air handlers (e.g., bathroom fans, clothes dryers, kitchen vent hood, attic fan) shall be turned off.
- 4.2.3. All vented combustion appliances shall be turned off if there is a possibility that the space containing the appliance will be depressurized during the test procedure.
- 4.2.4. All filters in the duct system and air handler cabinet shall be removed. If the Duct Leakage Tester is installed at a return grille, any filters present at that grille shall also be removed. If present, filter slot cover(s) shall be replaced after removing filters.
- 4.2.5. Dampers within the duct system shall be treated as follows:
 - 4.2.5.1. Non-motorized dampers (e.g., pressure-activated operable dampers, fixed dampers) that connect the conditioned space (including space conditioning duct systems) to the exterior or to unconditioned spaces shall be left in their as-found positions. For example, a fixed damper in a duct supplying outdoor air for an intermittent ventilation system that utilizes the HVAC fan shall be left in its as-found position.
 - 4.2.5.2. Motorized dampers that connect the conditioned space (including space conditioning duct systems) to the exterior or to unconditioned spaces shall be placed in their closed positions and shall not be further sealed.
 - 4.2.5.3. All zone and bypass dampers shall be set to their open position to allow uniform pressures throughout the duct system.
 - 4.2.5.4. All balancing dampers shall be left in their as-found position.
- 4.2.6. Non-dampened ventilation openings within the duct system shall be treated as follows:
 - 4.2.6.1. Non-dampened ventilation openings of intermittently operating whole-house ventilation systems, including HVAC fan-integrated outdoor air inlets, that connect the conditioned space (including space conditioning duct systems) to the exterior or to unconditioned spaces shall not be sealed.

4.2.6.2. Non-dampered ventilation openings of continuously operating whole-house ventilation systems that connect the conditioned space (including space conditioning duct systems) to the exterior or to unconditioned spaces shall be sealed, preferably at the exterior of the enclosure.

4.2.7. Supply registers and return grilles shall be temporarily sealed at both the face and the perimeter. Registers atop carpets are permitted to be removed and the face of the duct boot temporarily sealed during testing. For homes without registers and grilles present (e.g., new construction), the face of the duct boots shall be sealed instead.

4.3. Procedure to Install the Test Apparatus and Prepare for Leakage Test

There are two acceptable methods for attaching the Duct Leakage Tester to the duct system. Method 1 may only be used for duct systems with three or fewer return grilles.

Exception: If local codes require licensing that the inspector or rater conducting the test has not obtained in order to remove the blower access panel, Method 1 is permitted to be used even if there are more than three returns. Method 2 is permitted to be used for all systems.

- *Method 1 Installation.* The Duct Leakage Tester shall be attached to the return grille closest to the air handler. The remaining opening in the return grille shall be temporarily sealed.
- *Method 2 Installation.* The air handler blower access panel shall be removed and the Duct Leakage Tester attached to the blower compartment access.

4.3.1. If the duct leakage to outside will be measured then a Blower Door shall be installed in the enclosure per Section 3.3.1 and 3.3.2.

4.3.2. The pressure probe(s) for the Duct Leakage Tester shall be installed using one of the following options.

Note: *When using Method 1 for a duct system with more than three returns (based on the exception in Section 4.3), then Section 4.3.2.4 shall be used.*

4.3.2.1. A single pressure probe shall be located at the supply register closest to the air handler; or,

4.3.2.2. A single pressure probe shall be located in the main supply trunk line, at least 5 feet from the air handler; or,

4.3.2.3. A single pressure probe shall be located in the supply plenum; or,

4.3.2.4. A single pressure probe shall be located according to Section 4.3.2.1, 4.3.2.2, or 4.3.2.3, and a second probe shall be located in the return plenum or in the closest return grill to the air handler. The return duct system pressure probe shall not be located in the airstream of the duct tester.

4.3.3. The Manometer and tubing for the Duct Leakage Tester shall be connected to the pressure probe(s) installed in Section 4.3.2, in accordance with the manufacturer's instructions, so that the duct system pressure is capable of being measured with reference to the inside of the building.

If Section 4.3.2.4 has been selected, then both the supply- and return-side duct system pressure probes shall be connected to a "tee" fitting, and the third leg of the "tee" shall then be connected to the Manometer in the position indicated by the manufacturer's instructions to measure the duct system pressure.

4.3.4. The locations where the Duct Leakage Tester and pressure probe(s) have been installed shall be recorded.

4.4. Procedure to Conduct Leakage Test

The total leakage of the duct system shall be measured using the total duct leakage test in Section 4.4.1 or the leakage of the duct system to the outside shall be measured using the duct leakage to outside test in Section 4.4.2.

4.4.1. Total Duct Leakage Test

4.4.1.1. If ducts run through unconditioned spaces such as attics, garages or crawlspaces, any vents, access panels, doors, or windows between those spaces and the outside shall be opened. At least one door, window or comparable opening between the building and the outside shall be opened to prevent changes in building pressure when the Duct Leakage Tester is running.

4.4.1.2. The Duct Leakage Tester shall be turned on and adjusted to create an induced duct system pressure difference of 25 Pa (± 0.5 Pa). Note that this value is permitted to be positive or negative, which will be dependent upon whether the duct system is pressurized or depressurized.

If a 25 Pa (0.1 in. H₂O) induced duct system pressure difference can be achieved, then the average value of the duct system pressure difference and the airflow at 25 Pa (0.1 in. H₂O) (CFM_{25} , CMS_{25}), measured over at least a 10 second period, shall be recorded.

If a 25 Pa (0.1 in. H₂O) induced duct system pressure difference cannot be achieved, then the highest induced duct system pressure difference ($dP_{measured}$) and airflow ($CFM_{measured}$, $CMS_{measured}$) that was achieved with the equipment available, measured over at least a 10 second period, shall be recorded.

4.4.1.3. An indication of whether the Duct Leakage Tester is pressurizing or depressurizing the duct system shall be recorded.

4.4.1.4. The Duct Leakage Tester shall be turned off and the home returned to its as-found condition.

- 4.4.1.5.** If an induced duct system pressure difference of 25 Pa (0.1 in. H₂O) was not achieved in Section 4.4.1.2, then the recorded airflow ($CFM_{measured}$, $CMS_{measured}$) shall be converted to a nominal airflow at 25 Pa (0.1 in. H₂O) (CFM_{25} , CMS_{25}) using Equation 11. Alternately, a Manometer that is equipped to automatically make the conversion to CFM_{25} or CMS_{25} is permitted to be used.

$$CFM_{25} = CFM_{measured} \left(\frac{25}{dP} \right)^{0.6} \quad (11a)$$

$$CMS_{25} = CMS_{measured} \left(\frac{25}{dP} \right)^{0.6} \quad (11b)$$

4.4.2. Duct Leakage to Outside Test

- 4.4.2.1.** If ducts run through unconditioned spaces such as attics, garages or crawlspaces, any vents, access panels, doors, or windows between those spaces and the outside shall be in normal operating condition. All exterior doors and windows between the building and outside shall be closed, and other openings to the outside that may hinder the ability of the Air-Moving Fan to achieve an induced enclosure pressure difference of 25 Pa (0.1 in. H₂O) with reference to outside shall be closed or covered in some manner. Interior doors shall be opened.
- 4.4.2.2.** With the Air-Moving Fan for the enclosure and the Duct Leakage Tester sealed and turned off, one measurement of the pressure difference across the enclosure shall be recorded, with the outside as the reference. The measurement shall represent the average value over at least a 10 second period and shall be defined as the Pre-Test Baseline Building Pressure.
- 4.4.2.3.** The Air-Moving Fan for the enclosure shall be unsealed, turned on, and adjusted to create an induced enclosure pressure difference of 25 Pa (± 0.5 Pa) (0.1 ± 0.002 in. H₂O ± 0.002), defined as the induced enclosure pressure minus the Pre-Test Baseline Building Pressure. Note that this value is permitted to be positive or negative, which will be dependent upon whether the enclosure is pressurized or depressurized.
- If a 25 Pa (0.1 in. H₂O) induced enclosure pressure difference cannot be achieved, then the highest possible value up to 25 (0.1 in. H₂O) Pa shall be achieved with the equipment available.
- 4.4.2.4.** The Duct Leakage Tester shall be unsealed, turned on, and adjusted to create an induced duct system pressure difference of 0.0 Pa (± 0.5 Pa) (0.0 ± 0.002 in. H₂O), relative to the house. If an induced duct system pressure difference of 0.0 Pa (0.0 in. H₂O) cannot be achieved, the airflow of the Air-Moving Fan for the enclosure shall be reduced until an induced duct system pressure difference of 0.0 Pa (0.0 in. H₂O) can be achieved.

- 4.4.2.5.** The induced enclosure pressure difference shall be re-checked and, if necessary, the Air-Moving Fan for the enclosure shall be adjusted to maintain 25 Pa (0.1 in. H₂O) or the highest achievable value up to 25 (0.1 in. H₂O) Pa, per Section 4.4.2.3, or the airflow required to maintain an induced duct system pressure difference of 0.0 Pa (0.0 in. H₂O), per Section 4.4.2.4.
- 4.4.2.6.** The induced duct system pressure difference shall be re-checked and, if necessary, the Duct Leakage Tester shall be adjusted to maintain 0.0 Pa (± 0.5 Pa) (0.0 \pm 0.002 in. H₂O), per Section 4.4.2.4.
- 4.4.2.7.** Repeat 4.4.2.5 and 4.4.2.6 until the induced enclosure pressure difference is 25 Pa (0.1 in. H₂O) or the highest achievable value up to 25 Pa (0.1 in. H₂O) and the induced duct system pressure difference is 0.0 Pa (0.0 in. H₂O).
- If a 25 Pa (0.1 in. H₂O) induced enclosure pressure difference can be achieved, then the average value of the induced enclosure pressure difference, the induced duct system pressure difference, and the airflow at 25 Pa (0.1 in. H₂O) (CFM_{25} , CMS_{25}), measured over at least a 10 second period, shall be recorded.
 - If a 25 Pa (0.1 in. H₂O) induced enclosure pressure difference cannot be achieved, then the average value of the highest induced enclosure pressure difference (dP_{high}), the induced duct system pressure difference, and the airflow (Q_{high}) that was achieved with the equipment available, measured over at least a 10 second period, shall be recorded.
- 4.4.2.8.** An indication of whether the Air-Moving Fan for the enclosure is pressurizing or depressurizing the house and whether the Duct Leakage Tester is pressurizing or depressurizing the duct system shall be recorded.
- 4.4.2.9.** The Air-Moving Fan for the enclosure and the Duct Leakage Tester shall be turned off and the home returned to its as-found condition.
- 4.4.2.10.** If an induced enclosure pressure difference of 25 Pa (0.1 in. H₂O) was not achieved or a different value was used to achieve an induced duct system pressure difference of 0.0 Pa (0.0 in. H₂O), then the recorded airflow ($CFM_{measured}$, $CMS_{measured}$) shall be converted to a nominal airflow at 25 Pa (0.1 in. H₂O) (CFM_{25} , CMS_{25}) using Equation 11. Alternately, a Manometer that is equipped to automatically make the conversion to CFM_{25} or CMS_{25} is permitted to be used.

4.5. Procedure to Apply Results of Duct System Leakage Test

- 4.5.1.** If the results of the duct system leakage test are to be used for assessing compliance with a limit on total duct system leakage (e.g., defined by code or

by an energy efficiency program), then the total duct leakage determined in Section 4.4.1.2 or 4.4.1.5 shall be used.

4.5.2. If the results of the duct system leakage test are to be used for assessing compliance with a limit on duct system leakage to the outside (e.g., defined by code, by an energy efficiency program, or for a home energy rating), then the duct system leakage to outside determined in Section 4.4.2.7 or 4.4.2.10 shall be used. Alternatively, the total duct leakage determined in Section 4.4.1.2 or 4.4.1.5 is permitted to be used as if it were the leakage to outside (e.g., the total leakage value is permitted to be used in software as if it were leakage to the outside).

4.5.3. If the results of the duct system leakage test are to be used for conducting an energy audit or predicting savings from retrofits, then the duct system leakage to outside determined in Section 4.4.2.7 or 4.4.2.10 shall be used.

5. Procedure for Measuring Airflow of Mechanical Ventilation Systems

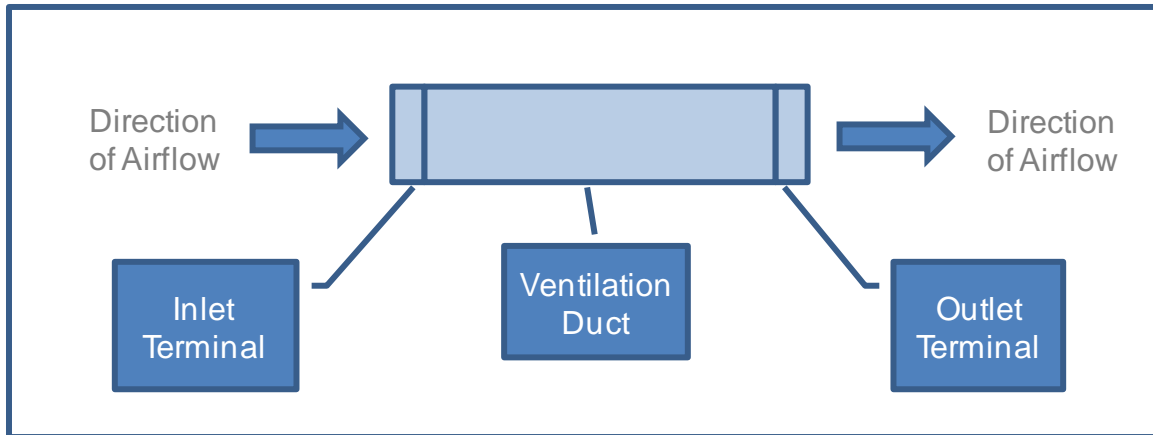
The purpose of this test procedure is to measure the volumetric airflow through a mechanical ventilation system, such as a whole-house ventilation system (e.g., ventilation inlet on the return side of an HVAC system, HRV, ERV) or a local mechanical exhaust system (e.g., bathroom exhaust fan, kitchen exhaust fan)¹.

The airflow is permitted to be measured at the inlet terminal, per Section 5.1; or at the outlet terminal, per Section 5.2; or mid-stream in the ventilation duct, per Section 5.3. Airflow measurements shall be verified to be in the acceptable range of airflow specified by the manufacturer for the equipment being used.

The inlet terminal is defined as the location where the ventilation air enters the mechanical ventilation system and the outlet terminal is defined as the location where the ventilation air exits the mechanical ventilation system. A diagram of these locations for a generic mechanical ventilation system is shown in Figure 1.

Figure 1: Location of Terminals in Generic Mechanical Ventilation System

¹ Informative Note: A multifamily building that has ventilation air supplied to corridors for the purpose of fresh air distribution to dwelling units does not have a ventilation system separate from other dwelling units, even if each dwelling has individual continuous exhaust ventilation. Although measurement of the individual dwelling exhaust could be considered within the scope of this standard, the overall ventilation system for each dwelling includes the central corridor supply system, and is thus outside the scope of this standard.



5.1. Procedure to Measure Airflow at Inlet Terminal

This Section defines procedures to measure the airflow of a mechanical ventilation system at an inlet terminal. The airflow is permitted to be measured using a Powered Flow Hood (Section 5.1.1); using an Airflow Resistance Device (Section 5.1.2); or using a Passive Flow Hood (Section 5.1.3).

5.1.1. Powered Flow Hood

5.1.1.1. Equipment Needed

5.1.1.1.1. Powered Flow Hood. A device consisting of a flow capture element capable of creating an airtight perimeter seal around the inlet terminal; an Airflow Meter capable of measuring the volumetric airflow through the flow capture element with an accuracy equal to or better than $\pm 5\%$ or 5 cfm (2.5 L/s or 0.0025 m³/s), whichever is greater; and a variable-speed Air-Moving Fan that is capable of moving air through the flow capture element and Airflow Meter.

5.1.1.1.2. Manometer. A device that can measure the static pressure inside the flow capture element relative to the room with an accuracy equal to or better than $\pm 5\%$ or 0.25 Pa (0.001 in. H₂O), whichever is greater.

5.1.1.2. Procedure to Conduct Airflow Test

5.1.1.2.1. The flow capture element of the Powered Flow Hood shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

5.1.1.2.2. The variable-speed Air-Moving Fan shall be turned on and the airflow adjusted until, using the Manometer, zero pressure difference (± 0.1 Pa (0.0004 in H₂O)) is measured between the flow capture element and the room.

5.1.1.2.3. The average volumetric airflow through the Airflow Meter, measured over at least a 10 second period, shall be recorded, and the variable-speed Air-Moving Fan shall be turned off.

5.1.2. Airflow Resistance Device

5.1.2.1. Equipment Needed

5.1.2.1.1. Airflow Resistance Device. A device consisting of a flow capture element that has a known opening area and is capable of creating an airtight perimeter seal around the inlet terminal.

5.1.2.1.2. Manometer. A device that can measure pressure difference with an accuracy equal to or better than $\pm 5\%$ or 0.25 Pa (0.001 in. H₂O), whichever is greater.

5.1.2.2. Procedure to Conduct Airflow Test

5.1.2.2.1. The flow capture element of the Airflow Resistance Device shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

5.1.2.2.2. The opening area of the Airflow Resistance Device shall be adjusted until, using the Manometer, the pressure difference between the flow capture element and the room is between 1 and 5 Pa.

5.1.2.2.3. The average pressure difference (dP) between the flow capture element and the room, measured over at least a 10 second period, shall be recorded.

5.1.2.2.4. Using the average pressure difference, the airflow shall be calculated using the manufacturer's flow conversion table or, for devices without a flow conversion table, the following equations:

$$\text{Airflow (CFM)} = \text{Opening Area} \times 1.07 \times (dP)^{0.5} \quad (12a)$$

$$\text{Airflow (L/s)} = \text{Opening Area} \times 0.078 \times (dP)^{0.5} \quad (12b)$$

Where:

For Eq. 12a, Opening Area is in in² and dP is in Pa

For Eq. 12b, Opening Area is in cm² and dP is in Pa

5.1.2.3. **Limitations of Procedure.** An Airflow Resistance Device is only permitted to be used on mechanical ventilation systems that do not have multiple duct branches.

5.1.3. Passive Flow Hood

5.1.3.1. Equipment Needed

5.1.3.1.1. Passive Flow Hood. A device consisting of a flow capture element capable of creating an airtight perimeter seal around the inlet terminal; and an Airflow Meter capable of measuring the volumetric airflow through the flow capture element with an accuracy equal to or better than $\pm 5\%$ or 5 cfm (2.5 L/s or 0.0025 m³/s), whichever is greater.

5.1.3.1.2. Manometer. A device that can measure pressure difference with an accuracy equal to or better than $\pm 5\%$ or 0.25 Pa (0.001 in. H₂O), whichever is greater.

5.1.3.2. Procedure to Conduct Airflow Test

5.1.3.2.1. The flow capture element of the Passive Flow Hood shall be placed over the inlet terminal, ensuring that an airtight perimeter seal has been created.

5.1.3.2.2. The pressure tubing shall be inserted inside the flow capture element between the Airflow Meter and inlet terminal.

5.1.3.2.3. The pressure difference between the flow capture element and the room shall be measured using the Manometer. If the pressure difference is more than 5 Pa, the procedure shall be terminated and no results recorded.

5.1.3.2.4. If the pressure difference is ≤ 5 Pa (0.02 in H₂O), then the average volumetric airflow through the Airflow Meter, measured over at least a 10 second period, shall be recorded.

5.2. Procedure to Measure Airflow at Outlet Terminal

This Section defines procedures to measure the airflow of a mechanical ventilation system at an outlet terminal. The airflow is permitted to be measured using a Powered Flow Hood (Section 5.2.1) or using a Bag Inflation Device (Section 5.2.2).

5.2.1. Powered Flow Hood. To measure airflow at an outlet terminal using a Powered Flow Hood, Section 5.1.1 shall be followed except with all occurrences of the phrase "inlet terminal" replaced with "outlet terminal".

5.2.2. Bag Inflation Device

5.2.2.1. Equipment Needed

5.2.2.1.1. Bag Inflation Device. A flow capture element capable of creating an airtight perimeter seal around the outlet terminal that is connected to a plastic bag of known volume and holds the bag open (e.g., a lightweight frame made of wood, plastic or metal wire), and a shutter that controls airflow into the bag.

The thickness of the plastic bag shall be selected such that three or more measurements of a single outlet terminal produce results that are within 20% of each other.

The volume of the plastic bag shall be selected such that the bag will completely fill with air from the outlet terminal in the range of 3 to 20 seconds.

5.2.2.1.2. Stopwatch. A stopwatch capable of recording elapsed time ± 0.1 seconds.

5.2.2.2. Procedure to Conduct Airflow Test

- 5.2.2.2.1. The bag shall be completely emptied of air and the shutter closed to prevent airflow into the bag.
- 5.2.2.2.2. The Bag Inflation Device shall be placed over the outlet terminal.
- 5.2.2.2.3. The shutter shall be rapidly removed and the Stopwatch started.
- 5.2.2.2.4. The Stopwatch shall be stopped when the bag is completely filled with air from the outlet terminal and the elapsed time recorded.
- 5.2.2.2.5. The airflow shall be calculated using the following equations:

$$\text{Airflow (CFM)} = \frac{8 \times \text{Volume}}{\text{Elapsed Time}} \quad (13a)$$

$$\text{Airflow (L/s)} = \frac{4 \times \text{Volume}}{\text{Elapsed Time}} \quad (13b)$$

Where:

Volume = The volume of the plastic bag, in gallons

Elapsed Time = The time that elapsed until the bag was filled, in seconds.

5.3. Procedure to Measure Airflow Mid-Stream in the Ventilation Duct

This Section defines a procedure to measure the airflow of a mechanical ventilation system mid-stream in the ventilation duct.

5.3.1. Equipment Needed

5.3.1.1. Airflow Measurement Station. An Airflow Measurement Instrument capable of simultaneously measuring and averaging velocity pressure at a minimum of five locations across a duct diameter with an accuracy equal to or better than +/- 10% or 5 CFM (2.5 L/s), whichever is greater, coupled with a section of permanently installed smooth-walled ductwork designed to facilitate accurate readings (i.e., the Station). The Airflow Measurement Instrument shall either be temporarily inserted into the Station for the duration of the procedure or be permanently installed as part of the Station (e.g., as part of a manufacturer-assembled device consisting of the instrument factory-mounted in a housing). In either case, the Airflow Measurement Instrument shall contain a port that allows it to be connected to a Manometer.

5.3.1.2. Manometer. A device that can measure pressure difference with an accuracy equal to or better than ± 5 % or 0.25 Pa (0.001 in. H₂O), whichever is greater.

5.3.2. Procedure to Conduct Airflow Test

5.3.2.1. The Air Flow Measurement Station shall be installed in an accessible location, per manufacturer's instructions, or it shall be verified that

such a device has been installed and is accessible. If the Airflow Measurement Instrument is not permanently installed, it shall be inserted into the measurement port of the Station.

- 5.3.2.2. To minimize turbulence and ensure an accurate reading, the installation shall be visually verified to comply with the Airflow Measurement Instrument's specifications for minimum distance to both upstream and downstream duct fittings and fan outlets.
- 5.3.2.3. The cross-sectional area of the duct at the Station shall be recorded in ft² or m².
- 5.3.2.4. The Manometer shall be connected to the Airflow Measurement Instrument, and the average velocity pressure, measured over at least a 10 second period, shall be recorded.
- 5.3.2.5. If the Airflow Measurement Instrument is not permanently installed, it shall be removed and the port sealed with a sheet metal plug or metallic tape.
- 5.3.2.6. Using the average velocity pressure, the average velocity in feet per minute (FPM) or meter per second (m/s) shall be calculated using the Airflow Measurement Instrument manufacturer's velocity conversion table or equation.
- 5.3.2.7. The following equation shall be used to convert the average velocity to airflow.

$$\text{Airflow (CFM)} = V \times A \quad (14a)$$

$$\text{Airflow (L/s)} = 1000 \times V \times A \quad (14b)$$

Where:

For Eq. 14a, V = Velocity, in fpm, and A = Cross-Sectional Duct Area, in ft².

For Eq. 14b, V = Velocity, in m/s, and A = Cross-Sectional Duct Area, in m².

7. References

ASHRAE Standard 62.2-2013 "Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings", ASHRAE, Atlanta, GA.

ASTM E1554-13 "Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization", published by ASTM International, www.astm.org

ASTM E779-10 "Standard Test Method for Determining Air Leakage Rate by Fan Pressurization", published by ASTM International, www.astm.org