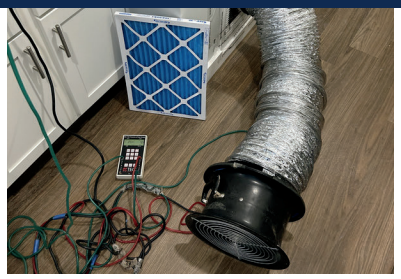
Duct Leakage Testing

2021 VRC/VECC Update Guide






Heating/Cooling Ductwork Must Meet Air-Tightness Standard:

Summary: Virginia began requiring duct airtightness to be measured with the 2015 Virginia Residential Code, with a maximum allowed leakage rate of 4%. If the air handler and ductwork of the HVAC system were within conditioned space, the system was exempt from testing. With the 2021 update, this exemption is removed, and all ducts serving or integrated with heating and cooling systems must be tested. Air handlers plus their associated ductwork located fully within conditioned space are allowed a maximum leakage rate of 8%. This guide is intended to give both code and real-world examples of what that change means for code enforcement in the Commonwealth.

Why: Testing to ensure heating/cooling ductwork does not exceed the leakage threshold is a simple, cost-effective way of improving comfort, air quality, and energy efficiency over the lifetime of that ductwork. Virginia's residential energy code began requiring heating/cooling ducts to be tested for leakage with the 2015 edition – but only for ductwork installed outside of the home's air barrier/thermal envelope. The maximum allowable leakage for those ducts is 4 percent. With the 2021 update, ductwork inside conditioned space also must be tested. Here, leakage must not exceed 8 percent. Duct leakage inside the building envelope compromises comfort, air quality, and moisture management – as well as energy efficiency. On the supply side, leaked air means some or all rooms do not receive the amount of conditioned air those rooms were intended to receive based on load calculations, equipment capacity, and the duct layout design. On the return side, leakage can mean return air is bypassing the filter.

Meeting N1103.3.6 (R403.3.6):

This test can take place at rough-in or after HVAC trim out has been completed. N1103.3.6 (R403.3.6) provides standards for leakage based on what components are installed during the time of the test and the stage of construction:

Air Handler and Ductwork not entirely within Conditioned Space

Test Conditions	Maximum Allowed Duct Leakage	Maximum Allowed (CFM25)
Rough-in with air handler installed	4 CFM per 100 sq ft of conditioned floor area	.04 x conditioned floor area served
Rough-in without air handler installed	3 CFM per 100 sq ft of conditioned floor area	.03 x conditioned floor area served
Post-construction	4 CFM per 100 sq ft of conditioned floor area	.04 x conditioned floor area served

Air Handler and Ductwork entirely within Conditioned Space

Test Conditions	Maximum Allowed Duct Leakage	Maximum Allowed (CFM25)
Rough-in with air handler installed	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served
Rough-in without air handler installed	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served
Post-construction	8 CFM per 100 sq ft of conditioned floor area	.08 x conditioned floor area served

Example
1 system serving the entire home. The system is in a vented attic. Conditioned floor area of the home is 1,200 sq. ft. Testing is done at the end of construction.

- 4% of conditioned floor area = 1,200 X 0.04 = 48
- To pass final duct leakage at final inspection: CFM25 must be ≤ 48 CFM

Per Section N1103.3.5 (R403.3.5), anyone that has been trained on the duct testing equipment to provide duct leakage measurements. Duct leakage is sometimes categorized as either "total" or "leakage to outside." The energy code only references total duct leakage.

Notes:

* Duct boot to drywall and duct boot to subfloor connections are typically the largest offenders for total leakage, including returns boot connections to drywall
* Duct boots can be easily covered by drywall and lead to higher leakage in the field
* Ventilation systems connected to the central heating and cooling system can also increase leakage if not operating properly
* Based on the Virginia Residential Energy Code Field Study results, 94% of systems tested in the participating homes in 2017 and 2018 were over the 4 cfm/100 sq ft threshold, with that dropping to an 84% failure rate with the conditioned space exemption applied
* Duct leakage drives infiltration, or air leakage, through the envelope; it can negatively or positively pressurize the house depending on where the ducts are leaking, pulling outside air in through cracks in the building envelope or pushing conditioned air out. If the duct leakage is in the supply-side ducts, the house will be negatively pressurized compared to outdoors. If all the leakage is on the return side, the building will be positive with respect to outdoors

Duct Sealing Visuals:

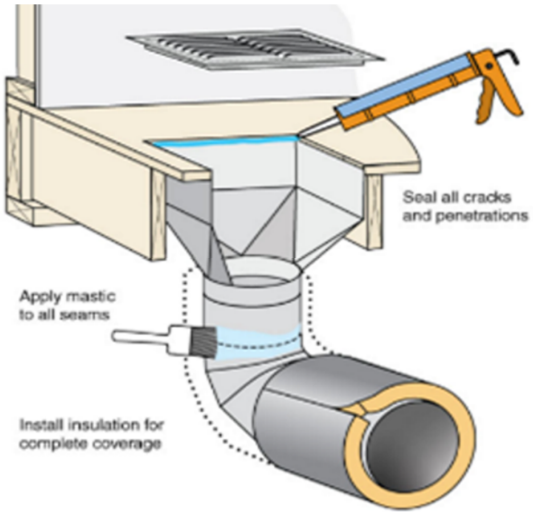


Figure 1: Joints and seams at duct boot sealed

Figure 2: Increased duct and envelope leakage if left unsealed

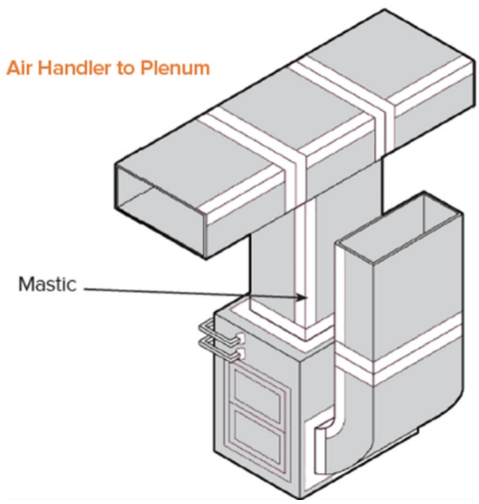


Figure 3: Well sealed plenum and trunk

Figure 4: Well sealed supply-to-trunk connection

Figure 5: Unsealed tabular duct takeoff

Figure 6: Unsealed and poorly supported duct takeoff. The immediate 90 degree turn should use hard duct.

Figure 7: Mastic paste used as permanent seal – "thick as a nickel"

Additional Resources:

- https://basc.pnnl.gov/resource-guides/total-duct-leakage-tests
- https://www.resnet.us/wp-content/uploads/ANSIRESNETICC_380-2019_vf1.24.19_cover%5E0TOC-2.pdf
  ANSI/RESNET/ICC 380-2019 Standard for Testing Airtightness of Building, Dwelling Unit, and Sleeping Unit Enclosures; Airtightness of Heating and Cooling Air Distribution Systems; and Airflow of Mechanical Ventilation Systems

2021 VRC/VECC Code References:

N1103.3 (R403.3) Ducts. Ducts and air handlers shall be installed in accordance with Sections N1103.3.1 through N1103.3.7.

N1103.3.1 (R403.3.1) Ducts located outside conditioned space. Supply and return ducts located outside conditioned space shall be insulated to an R-value of not less than R-8 for ducts 3 inches (76 mm) in diameter and larger and not less than R-6 for ducts smaller than 3 inches (76 mm) in diameter. Ducts buried beneath a building shall be insulated as required by this section or have an equivalent thermal distribution efficiency. Underground ducts utilizing the thermal distribution efficiency method shall be listed and labeled to indicate the R-value equivalency.

N1103.3.2 (R403.3.2) Ducts located in conditioned space. For ductwork to be considered inside a conditioned space, it shall comply with one of the following:

1. The duct system is located completely within the continuous air barrier and within the building thermal envelope.
2. Ductwork in ventilated attic spaces is buried within ceiling insulation in accordance with Section N1103.3.3 and all of the following conditions exist:
    2.1. The air handler is located completely within the continuous air barrier and within the building thermal envelope.
    2.2. The duct leakage, as measured either by a rough-in test of the ducts or a postconstruction total system leakage test to outside the building thermal envelope in accordance with Section N1103.3.6, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (9.29 m2) of conditioned floor area served by the duct system.
    2.3. The ceiling insulation R-value installed against and above the insulated duct is greater than or equal to the proposed ceiling insulation R-value, less the R-value of the insulation on the duct.
3. Ductwork in floor cavities located over unconditioned space shall have the following:
    3.1. A continuous air barrier installed between unconditioned space and the duct.
    3.2. Insulation installed in accordance with Section N1102.2.7.
    3.3. A minimum R-19 insulation installed in the cavity width separating the duct from unconditioned space.
4. 4.Ductwork located within exterior walls of the building thermal envelope shall have the following:
    4.1. A continuous air barrier installed between unconditioned space and the duct.
    4.2. Minimum R-10 insulation installed in the cavity width separating the duct from the outside sheathing.
    4.3. The remainder of the cavity insulation fully insulated to the drywall side.

N1103.3.3 (R403.3.3) Ducts buried within ceiling insulation. Where supply and return air ducts are partially or completely buried in ceiling insulation, such ducts shall comply with all of the following:

1. The supply and return duct shall have an insulation R-value not less than R-8.
2. At all points along each duct, the sum of the ceiling insulation R-values against and above the top of the duct, and against and below the bottom of the duct shall be not less than R-19, excluding the R-value of the duct insulation.

3. In Climate Zones 0A, 1A, 2A and 3A, the supply ducts shall be completely buried within ceiling insulation, insulated to an R-value of not less than R-13 and in compliance with the vapor retarder requirements of Section M1601.4.6.

    Exception: Sections of the supply duct that are less than 3 feet (914 mm) from the supply outlet shall not be required to comply with these requirements.

N1103.3.3.1 (R403.3.3.1) Effective R-value of deeply buried ducts. Where using the Total Building Performance Compliance Option in accordance with Section N1101.13.2, sections of ducts that are installed in accordance with Section N1103.3.3, located directly on or within 5.5 inches (140 mm) of the ceiling, surrounded with blown-in attic insulation having an R-value of R-30 or greater and located such that the top of the duct is not less than 3.5 inches (89 mm) below the top of the insulation, shall be considered as having an effective duct insulation R-value of R-25.

N1103.3.4 (R403.3.4) Sealing. Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply with Section M1601.4.1.

N1103.3.4.1 (R403.3.4.1) Sealed air handler. Air handlers shall have a manufacturer's designation for an air leakage of not greater than 2 percent of the design airflow rate when tested in accordance with ASHRAE 193.

N1103.3.5 (R403.3.5) Duct testing. Ducts shall be pressure tested in accordance with ANSI/RESNET/ICC 380 or ASTM E1554 to determine air leakage by one of the following methods:

1. 1.Rough-in test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the system, including the manufacturer's air handler enclosure if installed at the time of the test. Registers shall be taped or otherwise sealed during the test.
2. 2.Postconstruction test: Total leakage shall be measured with a pressure differential of 0.1 inch w.g. (25 Pa) across the entire system, including the manufacturer's air handler enclosure. Registers shall be taped or otherwise sealed during the test.

Exception: A duct air-leakage test shall not be required for ducts serving heating, cooling or ventilation systems that are not integrated with ducts serving heating or cooling systems.

A written report of the results of the test shall be signed by the party conducting the test and provided to the code official. The licensed mechanical contractor installing the mechanical system shall be permitted to perform the duct testing. The contractor shall have been trained on the equipment used to perform the test.

N1103.3.6 (R403.3.6) Duct leakage. The total leakage of the ducts, where measured in accordance with Section N1103.3.5, shall be as follows:

1. Rough-in test: The total leakage shall be less than or equal to 4.0 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m2) of conditioned floor area where the air handler is installed at the time of the test. Where the air handler is not installed at the time of the test, the total leakage shall be less than or equal to 3.0 cubic feet per minute (85 L/min) per 100 square feet (9.29 m2) of conditioned floor area.
2. Postconstruction test: Total leakage shall be less than or equal to 4.0 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m2) of conditioned floor area.

3. Test for ducts within thermal envelope: Where all ducts and air handlers are located entirely within the building thermal envelope, total leakage shall be less than or equal to 8.0 cubic feet per minute (226.6 L/min) per 100 square feet (9.29 m2) of conditioned floor area.

Exceptions:
1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Sections N1102.4.2 and R1006.

M1601.4.1 Joints, seams and connections. Longitudinal and transverse joints, seams and connections in metallic and nonmetallic ducts shall be constructed as specified in SMACNA HVAC Duct Construction Standards—Metal and Flexible and NAIMA Fibrous Glass Duct Construction Standards. Joints, longitudinal and transverse seams, and connections in ductwork shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), mastic-plus-embedded-fabric systems, liquid sealants or tapes. Tapes and mastics used to seal fibrous glass ductwork shall be listed and labeled in accordance with UL 181A and shall be marked "181A-P" for pressure-sensitive tape, "181 A-M" for mastic or "181 A-H" for heat-sensitive tape.

Tapes and mastics used to seal metallic and flexible air ducts and flexible air connectors shall comply with UL 181B and shall be marked "181 B-FX" for pressure-sensitive tape or "181 BM" for mastic. Duct connections to flanges of air distribution system equipment shall be sealed and mechanically fastened. Mechanical fasteners for use with flexible nonmetallic air ducts shall comply with UL 181B and shall be marked 181B-C. Crimp joints for round metallic ducts shall have a contact lap of not less than 1 inch (25 mm) and shall be mechanically fastened by means of not less than three sheet-metal screws or rivets equally spaced around the joint.

Closure systems used to seal all ductwork shall be installed in accordance with the manufacturers' instructions.
Exceptions:
1. Spray polyurethane foam shall be permitted to be applied without additional joint seals.
2. Where a duct connection is made that is partially without access, three screws or rivets shall be equally spaced on the exposed portion of the joint so as to prevent a hinge effect.
3. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems shall not be required for continuously welded joints and seams and locking-type joints and seams. This exception shall not apply to snap-lock and button-lock type joints and seams that are located outside of conditioned spaces.

M1601.4.6 Duct insulation. Duct insulation shall be installed in accordance with the following requirements:
1. A vapor retarder having a permeance of not greater than 0.05 perm [2.87 ng/(s × m2× Pa)] in accordance with ASTM E96, or aluminum foil with a thickness of not less than 2 mils (0.05 mm), shall be installed on the exterior of insulation on cooling supply ducts that pass through unconditioned spaces conducive to condensation except where the insulation is spray polyurethane foam with a water vapor permeance of not greater than 3 perms per inch [1722 ng/(s × m2× Pa)] at the installed thickness.
2. Outdoor duct systems shall be protected against the elements.
3. Duct coverings shall not penetrate a fireblocked wall or floor.

Definitions:

BUILDING THERMAL ENVELOPE: The basement walls, exterior walls, floors, ceiling, roofs and any other building element assemblies that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

CONDITIONED SPACE: An area, room or space that is enclosed within the building thermal envelope and that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

CONTINUOUS AIR BARRIER: A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

CONTINUOUS INSULATION (ci): Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

DUCT: A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

DUCT SYSTEM: A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

EXTERIOR WALL: Walls including both above-grade walls and basement walls.

LABELED: Equipment, materials or products to which have been affixed a label, seal, symbol or other identifying mark of a nationally recognized testing laboratory, approved agency or other organization concerned with product evaluation that maintains periodic inspection of the production of such labeled items and whose labeling indicates either that the equipment, material or product meets identified standards or has been tested and found suitable for a specified purpose.

INFILTRATION: The uncontrolled inward air leakage into a building caused by the pressure effects of wind, or the effect of differences in the indoor and outdoor air density or both.

LISTED: Equipment, materials, products or services included in a list published by an organization acceptable to the code official and concerned with evaluation of products or services that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services and whose listing states either that the equipment, material, product or service meets identified standards or has been tested and found suitable for a specified purpose.

R-VALUE (THERMAL RESISTANCE): The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h × ft2 × °F/Btu) [(m2 × K)/W]. *Note: In more general terms, resistance to heat flow of a single material, expressed as a whole number. Higher numbers denote higher resistance to heat flow.