Duct Leakage to Outdoors

Last Updated: 06/06/2018

Scope

If the heating and cooling duct distribution system is located in unconditioned space (e.g., a vented attic or crawlspace), test the ducts for air leakage to the outdoors (i.e., into unconditioned space) in addition to testing total duct leakage.

Use a testing protocol approved by Residential Energy Services Network (RESNET) ([RESNET 2013](https://www.ENERGY.gov/)). This testing is typically done by a home energy rater certified by RESNET.

- Test duct leakage after all components of the system have been installed and air sealed, including the air handler, the ductwork, the duct boots, and the register grilles atop the finished surfaces (e.g., drywall, carpeting, flooring).
- If there is more than one system in the home, assess leakage on a per-system, rather than per-home, basis.
- Visually inspecting ducts prior to drywall installation allows for easier corrections.
- Either visually inspect or duct blower test ventilation ducts (e.g., ducts used for a separately ducted ERV or HRV system).
- Testing to outdoors is not required by ENERGY STAR or codes if the ducts are located completely within the conditioned space of the home and if certain other conditions exist, as described in the Compliance tab.

See the [Compliance Tab](https://www.ENERGY.gov/) for related codes and standards requirements, and criteria to meet national programs such as DOE’s Zero Energy Ready Home program, ENERGY STAR Certified Homes, and Indoor airPLUS.
Duct leakage testing should be performed after all components of the system have been installed (including the air handler, ductwork, register boxes/boots, and all air devices such as diffusers, registers, or grills). Leakage limits should be assessed on a per-system, rather than per-home, basis. Duct leakage is determined and documented by a rater using a Residential Energy Services Network, Inc. (RESNET)-approved testing protocol. The accepted protocols are found in RESNET’s Mortgage Industry National Home Energy Rating Systems Standards, Chapter 8, Section 803.3 (RESNET 2006).

Duct leakage testing per RESNET standards is performed using a duct tester such as the Minneapolis Duct Blaster or the Retrotec Duct Tester. The duct tester consists of three components: a calibrated fan that is used to either pressurize or depressurize the duct, a device to measure fan flow and building pressure, and supplies such as cardboard and tape or adhesive plastic sheeting to seal off the supply and return registers during the test. The fan is used to pressurize or depressurize the duct system to 25 pascals (0.10 inch water column [IN WC]) (RESNET Standards). Once at 25 pascals pressure, the air flow through the duct tester is read in cubic feet of air flow per minute at 25 pascals; this measurement is abbreviated as CFM25.

Two types of tests are performed: total duct leakage and leakage to the outdoors:

The “total” duct leakage test measures how much leakage there is for all of the ductwork connected to the HVAC system, including ducts located both outdoors and indoors. The ENERGY STAR Qualified Homes Version 3 HVAC Quality Installation Rater Checklist Note 4.1 requires that “total” duct leakage be < 8 CFM25 per 100 square feet (ft²) of conditioned floor area. For more on total duct leakage testing, see Total Duct Leakage.

The “duct leakage to the outdoors” test measures only duct leakage outside of the home’s air barrier, i.e., leakage to the outdoors, for example, into an unconditioned attic or crawlspace. The ENERGY STAR Qualified Homes Version 3 HVAC Quality Installation Rater Checklist Note 4.2 requires that duct leakage to the “outdoors” be ≤ 4 CFM25 per 100 ft² of conditioned floor area. For smaller homes (those with ≤ 1,200 ft² of conditioned floor area), measured duct leakage to outdoors shall be ≤ 5 CFM25 per 100 ft² of conditioned floor area.

For ducts in unconditioned spaces, both tests should be conducted, according to ENERGY STAR Version 3, Rev 6.

When ducts are located in conditioned spaces, only the “total” duct leakage test needs to be conducted if certain conditions apply according to ENERGY STAR Version 3, Rev 6. Testing of duct leakage to the outside can be waived if all ducts and air handling equipment are located within the home’s pressure and thermal boundaries AND envelope leakage has been tested to be less than or equal to half of the Prescriptive Path infiltration limit for the Climate Zone where the home is to be built. Alternatively, testing of duct leakage to the outside can be waived if total duct leakage is ≤ 4 CFM25 per 100 ft² of conditioned floor area (or ≤ 5 CFM25 per 100 ft² of conditioned floor area for smaller homes that have less than 1,200 ft² of conditioned floor area).

The measured duct leakage can be compared to rated air handler flow to get a sense of the energy penalty that duct leaks are contributing in BTU/h. (This is not an ENERGY STAR requirement.) Cooling systems move 400 cubic feet of air per minute over the evaporator coil per ton of cooling. Each cubic foot of air moved will carry with it 30 BTU/h. A 2.5-ton cooling system moves 1,000 CFM of air and puts out 30,000 BTU/h. If that system has a measured duct leakage of 10% (100 CFM25), it is losing 3,000 BTU/h (1/4 ton) of cooling to outdoors.
Leakage limits are assessed on a per-system, rather than per-home, basis. So, for example, if a home has two furnaces, duct leakage must be measured in each system and compared to the square footage that the system conditions. Each system must meet the “total” and “outdoors” leakage requirements to qualify for the ENERGY STAR program.

**Figure 2** - The duct tester and blower door are set up to measure leakage to the outdoors. The blower door is set to depressurize the house to -25 pascals with respect to the outdoors. Then the duct tester is set to depressurize the duct system to 0 pascals with reference to the house. The flow reading on the right side of the manometer indicates duct leakage to the outside in CFM. In this case, duct leakage to the outdoors is 100 CFM at 25 pascals. Some raters prefer to do this test with the fans reversed so that they pressurize the house and ducts to 25 pascals rather than depressurizing the house to -25 pascals.

**How to Test Duct Leakage to the Outdoors**

1. Install a blower door in an exterior door that opens to a central location in the home. If the duct tester is set up to pressurize the duct system, then set up the blower door to pressurize the home. If the duct tester is set up to depressurize the duct system, set up the blower door to depressurize the home. Regarding pressurizing versus depressurizing, the test will work either way, the decision is up to the rater.

2. Close all exterior doors and windows between the building and the outside during the test.

3. Attach the duct that comes connected to the duct tester to the largest return duct grille using tape. Set up the duct tester per manufacturer’s instructions to either pressurize or depressurize the duct system (whichever is preferred).

4. Temporarily seal shut all of the other supply and return duct registers using cardboard and tape or removable adhesive plastic.

5. Turn on the blower door fan and bring the building pressure to 25 pascals with reference to the outdoors.

6. Turn on the duct tester fan and increase the air flow until the pressure inside the duct system is 0.0 (±0.1 pascal) with reference to the home. When both the house and the ducts are pressurized to 25 pascals with respect to outdoors, there should be no air flowing through duct leaks into the house. During this time, the blower door fan speed may have to be adjusted to make sure the home stays at 25 pascals with reference to outdoors.

7. Note on the manometer connected to the duct tester the amount of air flow needed to maintain the duct pressure at 0 pascals with reference to the home. This number, in CFM, is the amount of duct leakage to the outside of the home’s air barrier, i.e., leakage to the outdoors, for example into an unconditioned attic or crawlspace.

8. Take two measurements: the first measurement with the duct tester pressure probe in the return duct as shown in Figure 2 and the second with the duct tester pressure probe in a supply duct as far as possible from the return that the duct tester is connected to. Add both measurements together and divide by two. This will be the average measured duct leakage to the outdoors. Testing both the supply and return ducts can also show you where dominant sources of leakage are in the duct system, on the return side or on the supply side.
Ensuring Success

After ducts are installed and before drywall is installed, the duct system should be visually inspected by a HERS rater to ensure that all duct connections are properly fastened and sealed, preferably with mastic. After all HVAC components, including registers and grilles, have been installed over finished surfaces (such as drywall or carpeting), the ducts should be tested for air leakage and proper air flow.

A HERS rater should confirm and document that duct leakage to the outdoors is ≤ 4 cubic feet of air flow per minute at 25 pascals (CFM25) per 100 ft $^2$ of conditioned floor area using a RESNET-approved testing protocol, such as a duct blaster test. An optional, additional duct blaster test can be conducted prior to drywall installation to measure duct leakage. If the leakage level is above 4 CFM25 per 100 ft $^2$ of conditioned floor area, the builder, rater, or HVAC contractor may use a smoke machine to determine exact locations of leakage so they can be sealed before drywalling. If the Prescriptive Path has been chosen, the rater should also visually inspect that ducts are fully insulated (to R-8 for supply ducts and R-6 for returns and other ducts) along the length, including all connections, and that the insulation is not compressed by tight strapping, by framing members, or by excessive bending.
Climate

No climate-specific information applies.
Training

Right and Wrong Images

Display Image: ES_HVAC_QIRC_4.1-4.2_PG50_73b_102811.jpg
CAD
None Available
Compliance

The Compliance tab contains both program and code information. Code language is excerpted and summarized below. For exact code language, refer to the applicable code, which may require purchase from the publisher. While we continually update our database, links may have changed since posting. Please contact our webmaster if you find broken links.

ENERGY STAR Certified Homes, Version 3/3.1 (Rev. 09)

National Rater Field Checklist

HVAC System.
6.1 Ductwork installed without kinks, sharp bends, compressions, or excessive coiled flexible ductwork.footnote(33)
6.5 Rater-measured duct leakage to outdoors the greater of ? 4 CFM25 per 100 sq. ft. of CFA or ? 40 CFM25.footnote(36, 38, 41)

Footnote 33) Kinks are to be avoided and are caused when ducts are bent across sharp corners such as framing members. Sharp bends are to be avoided and occur when the radius of the turn in the duct is less than one duct diameter. Compression is to be avoided and occurs when flexible ducts in unconditioned space are installed in cavities smaller than the outer duct diameter and ducts in conditioned space are installed in cavities smaller than inner duct diameter. Ducts shall not include coils or loops except to the extent needed for acoustical control.

Footnote 36) Items 6.4 and 6.5 only apply to heating, cooling, and balanced ventilation ducts. Duct leakage shall be determined and documented by a Rater using the same version of ANSI / RESNET / ICC Std. 380 that is utilized by RESNET for HERS ratings. Leakage limits shall be assessed on a per-system, rather than per-home, basis. For balanced ventilation ducts that are not connected to space heating or cooling systems, a Rater is permitted to visually verify, in lieu of duct leakage testing, that all seams and connections are sealed with mastic or metal tape and all duct boots are sealed to floor, wall, or ceiling using caulk, foam, or mastic tape.

Footnote 38) For a home certified in the State of ID, MT, OR, or WA that is permitted before 01/01/2016, as an alternate to Rater-verified duct leakage, a PTCS® Duct Sealing Certification Form is permitted to be collected by the Home Energy Rater.

Footnote 41) Testing of duct leakage to the outside can be waived if all ducts & air handling equipment are located within the home’s air and thermal barriers AND infiltration does not exceed the following: CZ 1-2: 3 ACH50; CZ 3-4: 2.5 ACH50; CZ 5-7: 2 ACH50; CZ 8: 1.5 ACH50. Alternatively, testing of duct leakage to the outside can be waived if total duct leakage is ? 4 CFM25 per 100 sq. ft. of conditioned floor area or 40 CFM25, whichever is larger.

Please see the ENERGY STAR Certified Homes Implementation Timeline for the program version and revision currently applicable in your state.

DOE Zero Energy Ready Home (Revision 07)

Exhibit 1 Mandatory Requirements.
Exhibit 1, Item 1) Certified under the ENERGY STAR Qualified Homes Program or the ENERGY STAR Multifamily New Construction Program.

2009 IECC / 2009 IRC

IECC R403.2/IRC N1103.2 Ducts.

IECC R403.2.1/IRC N1103.2.1 Insulation (Prescriptive). Supply ducts in attics shall be insulated to a minimum of R-8. All other ducts shall be insulated to a minimum of R-6.

Exception: Ducts or portions thereof located completely inside the building thermal envelope.

IECC R403.2.2/IRC N1103.2.2 Sealing (Mandatory). All ducts, air handlers, filter boxes, and building cavities used as ducts shall be sealed. Joints and seams shall comply with Section M1601.4 of the International Residential Code. [Exceptions may apply.]

Duct tightness shall be verified by either of the following:

1. Post-construction test: leakage to outdoors shall be less than or equal to 8 cfm (226.5 L/min) per 100 ft² (9.29 m²) of conditioned floor area or a total leakage less than or equal to 12 cfm (339.8 L/min) per 100 ft² of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer’s air handler enclosure. All register boots shall be taped or otherwise sealed during the test.

2. Rough-in test: Total leakage shall be less than or equal to 6 cfm (169.9 L/min) per 100 ft² of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the roughed in system, including the manufacturer’s air handler enclosure. All register boots shall be taped or otherwise sealed during the test. If the air handler is not installed at the time of the test, total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 ft² of conditioned floor area.

Exceptions: Duct tightness test is not required if the air handler and all ducts are located within conditioned space.
IECC R403.2.3/IRC N1103.2.3 Building cavities (Mandatory). Building framing cavities shall not be used as supply ducts.

**2012 IECC / 2012 IRC**

IECC R403.2/IRC N1103.2 Ducts. Ducts and air handlers shall be in accordance with IECC R403.2.1 through R403.2.3 (IRC N1103.2.1-N1103.2.3).

IECC R403.2.1/IRC N1103.2.1 Insulation (Prescriptive). Same as 2009 IECC/IRC.

IECC R403.2.2/IRC N1103.2.1 Sealing (Mandatory). Ducts, air handlers, and filter boxes shall be sealed. Joints and seams shall comply with either the International Mechanical Code or International Residential Code, as applicable [Exceptions may apply.]

Exceptions:

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. Where a duct connection is made that is partially inaccessible, three screws or rivets shall be equally spaced on the exposed portion of the joint so as to prevent a hinge effect.
3. Continuously welded and locking-type longitudinal joints and seams in ducts operating at static pressures less than 2 inches of water column (500 PA) pressure classification shall not require additional closure systems.

Duct tightness shall be verified by either of the following:

1. Post-construction test: Total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 ft² (9.29 m²) of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the entire system, including the manufacturer’s air handler enclosure. All register boots shall be taped or otherwise sealed during the test.
2. Rough-in test. Total leakage shall be less than or equal to 4 cfm per (113.3 L/min) per 100 ft² (9.29 m²) of conditioned floor area when tested at a pressure differential of 0.1 inches w.g. (25 Pa) across the system, including the manufacturer’s air handler enclosure. All registers shall be taped or otherwise sealed during the test. If the air handler is not installed at the time of the test, total leakage shall be less than or equal to 3 cfm (85 L/min) per 100 ft² of conditioned floor area.
   Exception: The total leakage test is not required for ducts and air handlers located entirely within the building thermal envelope.

IECC R403.2.2.1/IRC N1103.2.2.1 Sealed air handler. Air handler shall have a manufacturer’s designation for an air leakage of no more than 2 percent of the design air flow rate when tested in accordance with ASHRAE 193.

IECC R403.2.3/IRC N1103.2.3 Building cavities (Mandatory). Building framing cavities shall not be used as ducts or plenums.

**2015 and 2018 IECC / 2015 and 2018 IRC**

IECC R403.3/IRC N1103.3 Ducts. Ducts and air handlers shall be in accordance with Sections R403.3.1 through R403.3.5 (IRC N1103.3.1-N1103.3.5).

IECC R403.3.1/IRC N1103.3.1 Insulation (Prescriptive). Supply and return ducts in attics shall be insulated to a minimum of R-8 where 3 inches (76 millimeters) in diameter and greater and R-6 where less than 3 inches (76 millimeters) in diameter. Supply and return ducts in other portions of the building shall be insulated to a minimum of R-6 where 3 inches (76 millimeters) in diameter or greater and R-4.2 where less than 3 inches (76 millimeters) in diameter.

Exception: Ducts or portions thereof located completely inside the building thermal envelope.

IECC R403.3.2/IRC N1103.3.2 Sealing (Mandatory). Ducts, air handlers, and filter boxes shall be sealed. Joints and seams shall comply with either the International Mechanical Code or International Residential Code, as applicable.

Exceptions [In 2015 IECC/IRC only; these exceptions were not included in the 2018 IECC/IRC.]

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. 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 of other than the snap-lock and button-lock types.

IECC R403.3.2.1/IRC N1103.3.2.1 Sealed Air Handler. Air handlers shall have a manufacturer’s designation for an air leakage of no more than 2% of the design air flow rate when tested in accordance with ASHRAE 193.

IECC R403.3.3/IRC N1103.3.3 Duct testing (mandatory). Ducts shall be pressure tested to determine air leakage by one of the following methods:

1. Rough-in test. Total leakage shall be measured with a pressure differential of 0.1 inch water gage (25 Pa) across the system, including the manufacturer’s air handler enclosure if installed at the time of the test. All registers shall be taped or otherwise sealed during the test.
2. **Post-construction test.** Total leakage shall be measured with a pressure differential of 0.1 inch water gage (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 where the ducts and air handlers are located entirely within the *building thermal envelope*.

[New Exception added to 2018 IECC/IRC] A duct air leakage test shall not be required for ducts serving heat or energy recovery ventilators 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. [Because the ducts will be installed outside the *building thermal envelope*, this exception would not apply.]

IECC R403.3.4/IRC N1103.3.4 Duct leakage (Prescriptive).

The total leakage of the ducts, where measured in accordance with Section R403.3.3, shall be as follows:

1. **Rough-in test.** The total leakage shall be less than or equal to 4 cfm per (113.3 L/min) per 100 ft\(^2\) (9.29 m\(^2\)) 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 cfm (85 L/min) per 100 ft\(^2\) of conditioned floor area.

2. **Post-construction test:** Total leakage shall be less than or equal to 4 cfm (113.3 L/min) per 100 ft\(^2\) (9.29 m\(^2\)) of conditioned floor area.

IECC R403.3.5/IRC N1103.3.5 Building cavities (Mandatory). Building framing cavities shall not be used as ducts or plenums.

**2009, 2012, 2015, and 2018 IRC**

Ducts are designed, constructed, and installed in accordance with the provisions of IRC M1601 and M1602, ACCA Manual D, and manufacturers’ guidance.


Section R101.4.3 (Section R501.1.1 in 2015 and 2018 IECC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)


Section N1101.3 (Section N1107.1.1 in 2015 and 2018 IRC). Additions, alterations, renovations, or repairs shall conform to the provisions of this code, without requiring the unaltered portions of the existing building to comply with this code. (See code for additional requirements and exceptions.)

Appendix J regulates the repair, renovation, alteration, and reconstruction of existing buildings and is intended to encourage their continued safe use.
References and Resources*

1. **2009 IECC - International Energy Conservation Code**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2009  
   Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

2. **2009 IRC - International Residential Code for One and Two Family Dwellings**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2009  
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2012  
   Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

4. **2012 IRC - International Residential Code for One and Two Family Dwellings**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** January, 2012  
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

5. **2015 IECC - International Energy Conservation Code**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** May, 2014  
   Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems and service water heating systems in homes and commercial businesses.

6. **2015 IRC - International Residential Code for One and Two Family Dwellings**  
   **Author(s):** International Code Council  
   **Organization(s):** ICC  
   **Publication Date:** May, 2014  
   Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

7. None Available
2018 IECC - International Energy Conservation Code
Author(s): International Code Council
Organization(s): ICC
Publication Date: November, 2017
Code establishing a baseline for energy efficiency by setting performance standards for the building envelope (defined as the boundary that separates heated/cooled air from unconditioned, outside air), mechanical systems, lighting systems, and service water heating systems in homes and commercial businesses.

8. 2018 IRC - International Residential Code for One and Two Family Dwellings
Author(s): International Code Council
Organization(s): ICC
Publication Date: August, 2017
Code for residential buildings that creates minimum regulations for one- and two-family dwellings of three stories or less. It brings together all building, plumbing, mechanical, fuel gas, energy and electrical provisions for one- and two-family residences.

9. ACCA Manual D - Residential Duct Systems
Author(s): Air Conditioning Contractors of America
Organization(s): Air Conditioning Contractors of America
Publication Date: December, 2013
Standard outlining industry procedure for sizing residential duct systems.

10. DOE Zero Energy Ready Home National Program Requirements (Rev. 07)
Author(s): U.S. Department of Energy
Organization(s): DOE
Publication Date: May, 2019
Standard requirements for DOE's Zero Energy Ready Home national program certification.

11. ENERGY STAR Certified Homes, Version 3/3.1 (Rev. 09) National Program Requirements
Author(s): U.S. Environmental Protection Agency
Organization(s): EPA
Publication Date: September, 2018
Webpage with links to documents providing the program requirements and checklists for ENERGY STAR Certified Homes (Ver. 3/3.1, Rev. 09).

Author(s): RESNET
Organization(s): RESNET
Publication Date: January, 2013
RESNET standards aimed to ensure that accurate and consistent home energy ratings are performed by accredited home energy rating providers through their raters nationwide.

*Publication dates are shown for formal documents. Dates are not shown for non-dated media. Access dates for referenced, non-dated media, such as web sites, are shown in the measure guide text.

Contributors to this Guide
The following authors and organizations contributed to the content in this Guide.

Calcs-Plus
Pacific Northwest National Laboratory