Encapsulated Ducts

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Scope

When HVAC ducts are installed in a vented attic in any climate, encapsulate the ducts in closed-cell spray polyurethane foam (ccSPF) to protect them from temperature extremes in the unconditioned attic space.

- Where possible, install ductwork so that it is in direct contact with (i.e., laying on) the ceiling and/or truss lower cords. Where all or some portion of the ducts cannot be laid on the attic floor (due to truss design or some other obstacle), then hang the ducts using straps or saddles to properly support the ducts.
  - Use metal, flex, or fiber board ducts that are insulated to code. The duct insulation should include a vapor barrier cover.
  - See the guide Support at Intervals for Flex Ducts for more on properly supporting ducts.
- Mechanically fasten and mastic-seal all duct connections.
- Test total duct leakage. Add additional sealant if necessary.
- Completely encase the ducts in closed-cell spray polyurethane foam (ccSPF) to the desired foam depth.
- This technique is appropriate for all climates including the humid or marine climates.
- This technique fulfills the DOE Zero Energy Ready Home program requirement that ducts be installed in conditioned space.

See the Compliance Tab 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.
Description

For homes with ducted heating and cooling systems, the best place to locate the duct system from an HVAC performance standpoint is within the conditioned space of the home, either in dropped ceilings, or between floors, or in a sealed and insulated basement, crawlspace, or attic. If the ducts must be located within a vented attic, one option for protecting the ducts and helping to minimize heat transfer between ducts and the unconditioned attic is to bury the ducts in the attic floor insulation. Where all or some portion of the ducts cannot be laid on the attic floor (due to truss design or some other obstacle), then the ducts can be hung or supported above the attic floor and encapsulated in closed-cell spray polyurethane foam insulation.

Metal, flex, or fiber board ducts can be used. The ducts should be covered with R-8 or higher duct insulation and the duct insulation should include a vapor barrier cover. All duct connections should be mechanically fastened and mastic-sealed. The ducts should be tested for total duct leakage and any leaks should be sealed. The ducts should be hung using straps or saddles to properly support the ducts. See the guide Support at Intervals for Flex Ducts for more on properly supporting ducts. Once these preparations are made, the ducts can be encapsulated in at least 1.5 inches of closed-cell polyurethane spray foam. Encapsulating the ducts in spray foam increases the R-value of the ductwork and reduces air leakage. The effective R-value of an encapsulated duct installation depends on the size of the ducts, the R level of the duct insulation, and the thickness of the ccSPF insulation. For example, the effective R-value of an 8-inch round duct encapsulated with 1.5 inches of ccSPF is R-12.7.

How to Install Encapsulated Ducts

1. **Install** ductwork with a minimum of R-8 duct insulation in accordance with low-profile duct design (Figure 1).

2. **Properly fasten and seal** ducts at all connections. To attach flex duct, pull back outer liner, fasten inner liner over collar with tool-tightened tension tie, mastic seal the connection. Pull insulation and outer liner over the joint and seal to attached duct or boot with mastic or foil tape (Figure 2). The outer liner should not be attached with a tie as shown here but should be connected with mastic or foil tape to avoid compressing the insulation.

3. **Test total duct leakage** to ensure that the ducts have been adequately sealed (total duct leakage < 3 cfm25 per 100 ft2 of conditioned space, Figure 3). Testing should be performed before encapsulation because it may be difficult to correct sealing issues after the application of spray foam.
Figure 3. A duct blaster is used to test total duct leakage (Steven Winter Associates 2013).

4. **Apply at least 1.5 inches of ccSPF to all duct surfaces**, including trunks, branches, and register boots. Ducts should be entirely encapsulated (see the Scope image).
Ensuring Success

To minimize air leaks and maximize effective R-values, ccSPF must be applied to all surfaces to the ductwork. All duct connections should be mastic sealed and ducts should be tested for leakage with a duct blaster before the ccSPF is applied.

The 2009 IRC allows exposed installations of ccSPF in attics, but the spray foam must be specifically approved for installation without an ignition barrier.
Climate

Encapsulated ducts may be installed in all climate zones, including moist (A) and marine (C) climate zones.

IECC Climate Zone Map

All of Alaska is in Zone 7 except for the following boroughs in Zone 8:
Bethel, Northwest Arctic, Dillingham, Southeast Fairbanks, Fairbanks N. Star, Wade Hampton, Nome, Yukon-Koyukuk, North Slope

Zone 1 includes Hawaii, Guam, Puerto Rico, and the Virgin Islands
Training

Right and Wrong Images

Display Image: Wrong.Ductwork is not fully encapsulated.jpg
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.
6.3 All supply and return ducts in unconditioned space, including connections to trunk ducts, are insulated to \( R \geq 6 \). 35
6.4 Rater-measured total duct leakage meets one of the following two options. Alternative in Footnote 37: 36, 37, 38
6.4.1 Rough-in: The greater of \( 4 \) CFM\( ^{25} \) per 100 sq. ft. of CFA or \( 40 \) CFM\( ^{25} \), with air handler & all ducts, building cavities used as ducts, & duct boots installed. In addition, all duct boots sealed to finished surface, Rater-verified at final. 39
6.4.2 Final: The greater of \( 8 \) CFM\( ^{25} \) per 100 sq. ft. of CFA or \( 80 \) CFM\( ^{25} \), with the air handler & all ducts, bldg. cavities used as ducts, duct boots, & register grilles atop the finished surface (e.g., drywall, floor) installed. 40
6.5 Rater-measured duct leakage to outdoors the greater of \( 4 \) CFM\( ^{25} \) per 100 sq. ft. of CFA or \( 40 \) CFM\( ^{25} \). 36, 38, 41

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.
Exhibit 1, Item 3) Duct distribution systems located within the home’s thermal and air barrier boundary or an optimized location to achieve comparable performance.

Footnote 14) Exceptions and alternative compliance paths to locating 100% of forced-air ducts in home’s thermal and air barrier boundary are:
1. Up to 10’ of total duct length is permitted to be outside of the home’s thermal and air barrier boundary.
2. Ducts are located in an unvented attic, regardless of whether this space is conditioned with a supply register.
3. Ducts are located in a vented attic with all of the following characteristics: [Note that in either of these designs the HVAC equipment must still be located within the home’s thermal and air barrier boundary.]
   1. In Moist climates (Zones 1A, 2A, 3A, 4A, 5A, 6A and 7A per 2015 IECC Figure R301.1) and Marine climates (all “C” Zones per 2015 IECC Figure R301.1), minimum R-8 duct insulation with an additional minimum 1.5” of closed-cell spray foam insulation encapsulating the ducts; duct leakage to outdoors \( < 3 \) CFM\( ^{25} \) per 100 ft\( ^2 \) of conditioned floor area (in addition to meeting total duct leakage requirements from Section 4.1 of the ENERGY STAR HVAC Rater checklist); and ductwork buried under at least 2” of blown-in insulation.
   2. In Dry climates (all “B” Zones per 2015 IECC Figure R301.1), minimum R-8 duct insulation; duct leakage to outdoors \( < 3 \) CFM\( ^{25} \) per 100 ft\( ^2 \) of conditioned floor area (in addition to meeting total duct leakage requirements from Section 4.1 of the ENERGY STAR HVAC Rater checklist); and ductwork buried under at least 3.5” of blown-in insulation.
4. Systems which meet the criteria for “Ducts Located in Conditioned Space” as defined by the 2018 IECC Section R403.3.7
5. Jump ducts which do not directly deliver conditioned air from the HVAC unit may be located in attics if all joints, including boot-to-drywall, are fully air sealed with mastic or foam, and the jump duct is fully buried under the attic insulation.
6. Ducts are located within an unvented crawl space.
7. Ducts are located in a basement which is within the home’s thermal boundary.
8. Ductless HVAC system is used.


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 (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 6 cfm (169.9 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 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 (9.29 m²) of conditioned floor area.

Exceptions: The total leakage test is not required if the air handler and all ducts are located entirely within the building thermal envelope.

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

IECC R403.2/IRC N1103.2 Ducts. Ducts and air handlers shall be in accordance with Sections 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 (9.29 m²) of conditioned floor area.

IECC R403.2.2/IRC N1103.2.2 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.

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 ft² (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 cfm (85 L/min) per 100 ft² 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 ft² (9.29 m²) 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.

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.)

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

1. **Building America Top Innovations 2013 Profile: Buried and Encapsulated Ducts**  
   **Author(s):** PNNL  
   **Organization(s):** PNNL, CARB, Steven Winter Associates  
   **Publication Date:** September, 2013  
   Case study on a DOE Building America 2013 top innovation describing research by the Consortium for Advanced Residential Buildings (CARB), a Building America research team led by Steven Winter Associates, on HVAC ducts located in vented attics that are encapsulated in foam and buried in attic insulation.

2. **Technology Solutions Case Study: Buried and Encapsulated Ducts, Jacksonville, Florida**  
   **Author(s):** CARB  
   **Organization(s):** CARB  
   **Publication Date:** November, 2013  
   Case study exploring how using buried and/or encapsulated ducts can reduce duct thermal losses in existing homes.

References and Resources*

1. **Measure Guideline: Buried and/or Encapsulated Ducts**  
   **Author(s):** Shapiro, Zoeller, Mantha  
   **Organization(s):** CARB, Steven Winter Associates, SWA  
   **Publication Date:** August, 2013  
   Document covering the technical aspects of buried and insulated ducts (BEDs), as well as the advantages, disadvantages, and risks of BEDs compared to alternative strategies.

2. **Reducing Thermal Losses and Gains With Buried and Encapsulated Ducts in Hot-Humid Climates**  
   **Author(s):** Shapiro, Magee, Zoeller  
   **Organization(s):** CARB, Steven Winter Associates, SWA  
   **Publication Date:** February, 2013  
   Report including an overview of the buried duct research and information the retrofit methodology used to install and test the three existing duct systems, including short- and long-term data collection.

*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.