Buried Ducts within Ceiling Insulation of Vented Attics in all Climate Zones - Code Compliance Brief

Overview:

The intent of this brief is to provide code-related information about buried ducts within ceiling insulation of vented attics to help ensure that the measure will be accepted as being in compliance with the code. Providing notes for code officials on how to plan review and conduct field inspections can help provide jurisdictional officials with information for acceptance. Providing the same information to all builders, designers, and others is expected to result in increased compliance and fewer innovations being questioned at the time of plan review and/or field inspection.

Codes, standards, and regulations (CSRs) governing the design, construction, installation, commissioning, and operation of the built environment are intended to protect public health, safety and welfare. These documents change over time to address new technology and safety challenges, so there is generally some lag time between the introduction of a technology into the market and the time it is specifically covered in model codes and standards developed in the voluntary sector. Development of a new code or standard can take 3 to 4 years from the initiation of the effort until the result is adopted. Typically this takes on the order of 4 to 5 years and in some cases due to recent efforts to reduce the frequency of adoptions at the state and local level it could be over 6 years before new provisions covering new technologies are adopted. So, those seeking to design and construct using new technologies and alternative methods, or needing to verify an installation’s safety may find it challenging to apply current CSRs to a new technology or method such as buried ducts within ceiling insulation. Even when codes provide specific criteria, those deploying the new technology must document compliance with the CSRs and those enforcing compliance must be able to verify it with their CSRs.

Ducts buried within ceiling insulation of vented attics are not addressed in the 2015 and prior versions of the International Energy Conservation Code (IECC) or International Residential Code (IRC). This measure was an identified code barrier because it was not explicitly addressed by the previous model codes (IECC/IRC). This lack of direction within the code led many jurisdictions to prohibit the use of buried ducts out of concerns of condensation and reduced energy efficiency. Fortunately, the Department of Energy Building America program has researched the buried duct concept in a variety of projects for over 15 years addressing these concerns. Recently under the Building America program, Home Innovation Research Labs, researched duct placement and insulation and potential for condensation issues for both partially and deeply buried ducts in ceiling insulation in vented attics in all climate zones. The new alternative methods were successfully installed, tested, and monitored and found to be nearly as effective as requiring that ducts be installed in conditioned spaces (inside the inside the air barrier or building thermal envelope [defined as the basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space]). New provisions have been incorporated into the 2018 IECC/IRC that provide new options that will likely reduce the cost of construction and increase the energy efficiency of a house with ducts in an attic. Burying ducts within ceiling insulation and tightly sealing the ducts are a less expensive and more energy efficient solution than creating a conditioned attic. Additionally, it is often a more practical and homeowner friendly solution than installing bulkheads in the ceiling to keep ducts in conditioned space.

These alternative methods are endorsed by Building America and were submitted to the International Code Council (ICC) as a proposed code changes for the 2018 IECC/IRC code cycle. The proposed code changes made it through the rigorous 2018 code development cycle and are now published as new provisions in the 2018 IECC and the energy chapter of the 2018 IRC. (The new code sections are listed below under the Plan Review section.)

How do builders, designers, and code officials comply with the new provisions? States and local jurisdictions can have unique adoption processes with their own legislative and regulatory adoption language and code adopting bodies that adopt different building codes and code versions (e.g., 2009, 2012, 2015, or newly published 2018 IECC/IRC). For states and local jurisdictions that have not adopted the 2018 IECC and/or IRC, one approach to overcome this barrier would be to reference the most recent version of the IECC/IRC for guidance. The building code (IRC/IECC) allows for alternative materials, design, and methods of construction and equipment not specifically prescribed by code and this would include consideration of new guidance published in more recent versions of model codes. Consequently, the code official has the authority and responsibility to review and approve the proposed design as satisfactory and compliant with the intent of the provisions of the code (per Section R104.11/IRC, Section R102.1/IECC) as a means of achieving code compliance. The alternative materials, design, and methods provision has been a long-standing allowance and this important tradition has been continued in every version of the IRC/IECC. The alternative methods section in the IECC/IRC is below:

**2018/2015 IECC/IRC, Section R102.1/R104.11 Alternative Materials, Design and Method of Construction and Equipment.**

The code is not intended to prevent the installation of any material or prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. The code official (CO) is permitted to approve an alternative material, design, or method of construction where the CO finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and the material, method, or work offered is for the purpose intended, or at least the equivalent of that prescribed in the code.

So why encourage moving the duct system back outside the building thermal envelope (outside the air barrier), which at first read appears to be contrary to the language in the codes that encourages moving the duct system inside the building thermal envelope? In short, buried ducts in vented attics, provides a cost-effective, energy-efficient alternative solution to installing ducts inside conditioned space. This is particularly useful for avoiding challenges in many house configurations, including single-story, slab-on-
grade, and two-story houses with complicated framing or open floor plans. Adapting house designs with standard interior ducts may require the addition of mechanical rooms, duct chases, dropped ceilings, soffits, or floors. The additional framing and associated air sealing may not be acceptable to buyers, and air-distribution performance can be adversely affected due to increased duct lengths and bends.

Moving the ducting outside the building thermal envelope using the alternate system requires the ducts to be insulated, sealed, installed close the ceiling in a vented attic, and covered with attic insulation to minimize energy loss. Based on Building America research, ducts insulated to a minimum R-8 with common duct insulation material, sealed with conventional duct sealing material, and covered with a minimum R-30 attic insulation performed without any condensation issues. Furthermore, research demonstrated that the attic duct area was reduced by 32% for supply ducts and 75% for return ducts compared to builder standard practice which significantly contributed to the overall energy savings (D. Mallay, Home Innovation Research Labs, January 2016.)

For more detailed information on the Building America research for buried ducts within ceiling insulation of vented attics, refer to the last section on Technical Validation and References of this code compliance brief. Consider encapsulating the ducts and installing a compact duct design which will increase energy savings even further. These resources include example duct designs, acceptable best practices, case studies, and a summary of research findings. The next section (Plan Review) lists current code sections applicable to buried ducts within ceiling insulation of vented attics.

Plan Review:
This section lists the applicable code requirements and details helpful for plan review regarding the provisions to meet the requirements for buried ducts within ceiling insulation of vented attics in all climates zones. This brief covers the 2018 and 2015 IECC/IRC provisions specific to this measure. The lists and provisions provided in each section below are intended to target the main code sections and provisions. Other references, code sections, standards, testing methods, etc., that affect the technology or other assemblies or functions of the building may exist.

2018/2015 IECC, Section 103.1 General. Construction documents, technical reports or other supporting data shall be submitted in one or more sets with each application for a permit. The documents shall be prepared by a registered design professional where required by the statues of the jurisdiction in which the project is to be constructed. Where special conditions exist, the code official is authorized to require necessary construction documents to be prepared by a registered design professional.

2015 IRC, Section R104.1 General. The code official has authority to render interpretations of this code and to adopt policies and procedures in order to clarify the application of its provisions. Such interpretations, policies and procedures shall be in conformance with the intent and purpose of this code.

Section R104.11.1 Tests. Whenever there is insufficient evidence of compliance with the provisions of this code, or evidence that a material or method does not conform to the requirements of this code, or in order to substantiate claims for alternative materials or methods, the code official has authority to require tests as evidence of compliance to be made at no expense to the code official for the period required for retention of public records.

Section R103.2/N1101.5 Information on construction documents. Construction documents should include:

- Duct design and construction materials
- Compliance path chosen with applicable compliance report documentation: R-value or U-factor calculation method, if a performance path is being used, insure that ducts are being modeled properly (R-25 where deeply buried.)
- R-values of supply and return ducts and duct air sealing details and sealant(s) (e.g., mastic, approved tape, caulking) on building plans and/or construction documents
- Ceiling assembly R-value and air sealing details and sealant(s) including location of continuous air barrier on building plans and/or construction documents

Section R103.3/R106.3 Examination of Documents, the code official must examine or cause to be examined construction documents for code compliance.

2018/2015 IECC/IRC, Section R403.3.2/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 IRC, as applicable.

2015 IECC/IRC Exceptions ONLY (these exceptions were voted for approval to delete in the 2018 code version):
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.

Section R403.3.2.1/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.

**Section R403.3.3/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.** 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.)

**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.

**Section R403.3.4/N1103.3.4 Duct Leakage (Prescriptive).** The total leakage of the ducts, measured in accordance with Section R403.3.3/N1103.3.3, shall be as follows:

- **Rough-in test.** The total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (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 cubic feet per minute (85 L/min) per 100 square feet (9.29 m$^2$) of conditioned floor area.

- **Post-construction test.** Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m$^2$) of conditioned floor area.

**Section R403.3.5/N1103.3.5 Building Cavities (mandatory).** Building framing cavities should not be used as ducts or plenums.

**Section R403.3.6/N1103.3.6 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. Supply and return ducts shall have an insulation R-value of not less than R-8.

2. At all points along each duct, the sum of the ceiling insulation R-value 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 1A, 2A, 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 604.11 of the **International Mechanical Code** or Section M1601.4.6 of the IRC, as applicable.

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

**Section R403.3.6.1 Effective R-value of deeply buried ducts.** Where using a simulated energy performance analysis, sections of ducts that are:

- installed in accordance with Section R403.3.6
- 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.

**Section R403.3.7 Ducts located in conditioned space.** For ducts to be considered as inside a conditioned space, such ducts shall comply with either of the following requirements:

1. The duct system shall be located completely within the continuous air barrier and within the building thermal envelope.

2. The ducts shall be buried within ceiling insulation in accordance with Section R403.3.6 and all of the following conditions shall 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 by either a rough-in test of the ducts or a post-construction total system leakage test to outside the building thermal envelope in accordance with Section R403.3.4, is less than or equal to 1.5 cubic feet per minute (42.5 L/min) per 100 square feet (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.

In addition to allowing ducts to be buried within ceiling insulation, this provision sets the requirements for ducts to be considered within conditioned space. The DOE Zero Energy Ready Home National Program (DOE Zero Energy Ready Home National Program Requirements [1] (Rev. 04). May 11, 2015,) defines ducts inside conditioned space states, “Duct distribution systems located within the home's thermal and air barrier boundary or optimized to achieve comparable performance.” Item “1)” under R403.3.7 provides for that with the established code definitions. However, it also allows a comparable performance alternative to that includes buried ducts with provision for condensation avoidance for humid climates. Research has shown that almost all of the benefit of locating ducts inside conditioned space can be achieved by locating the air handler in conditioned space but located ducts tested to be essentially leak-free in a vented attic buried under ceiling insulation. Section R403.3.7 provides for these conditions in that: the air handler must be located completely within the continuous air barrier and within the building thermal envelope; the ducts must be tested to an extremely low but still measurable level of leakage; the sum of the duct R-value and the ceiling insulation immediately above the duct is unchanged from the prescriptive or proposed ceiling insulation amount that would have otherwise been installed; and duct condensation avoidance in humid climates is provided for by referring back the provisions of Section R403.3.6.

Building Thermal Envelope Assembly (ceiling provisions)

2018/2015 IECC/IRC, Section R402.1.2/N1102.1.2 Insulation Criteria. The building thermal envelope must meet the requirements of Table R402.1.2/N1102.1.2, based on the climate zone specified in Chapter 3 and the building assemblies associated with the vented attic (ceilings) that are considered part of the building thermal envelope. (Per Building America research, a minimum R-30 attic insulation installed over the top of the ducts would be required.) Again, it should be noted, depending upon the code, location, and climate zone, the minimum R-value for attic insulation could be higher than R-30.

Below are the prescriptive compliance paths (R-value computation, u-Factor alternative, and total UA alternative). The Performance based and Energy Rating Index (ERI) compliance paths are not addressed in detail in this brief, however, these paths could be used to demonstrate compliance to these alternative methods through whole-building modeling.

Section R402.1.3/N1102.1.3 R-Value Computation. Insulation material used in layers, such as framing cavity insulation, or continuous insulation should be summed to compute the corresponding component R-value. Computed R-values should not include an R-value for other building materials or air films.

Excerpt from the Insulation Requirements by Component Table R402.1.2/N1102.1.2

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 Except Marine</th>
<th>5 and Marine 4</th>
<th>6</th>
<th>7, 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling R-value</td>
<td>30</td>
<td>38</td>
<td>38</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
</tbody>
</table>

Section R402.1.4/N1102.1.4 U-Factor Alternative. An assembly with a U-factor equal to or less than that specified in Table R402.1.4/N1102.1.4 should be permitted as an alternative to the R-value in Table R402.1.2/N1102.1.2.

Excerpt from the Equivalent U-factor Table R402.1.4/N1102.1.4

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 Except Marine</th>
<th>5 and Marine 4</th>
<th>6</th>
<th>7, 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling U-factor</td>
<td>0.035</td>
<td>0.030</td>
<td>0.030</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Section R402.1.5/N1102.1.5 Total UA Alternative. Where the total building thermal envelope UA, the sum of U-factor times assembly area, is less than or equal to the total UA resulting from multiplying the U-factors in Table R402.1.4/N1102.1.4 by the same assembly area as in the proposed building, the building would be considered to be in compliance with the Table R402.1.2/N1102.1.2. The UA calculation shall be performed using a method consistent with the ASHRAE Handbook of Fundamentals and include the thermal bridging effects of framing materials.

Section R402.2.3/N1102.2.3 Eave baffle. For air-permeable insulation in vented attics, a baffle should be installed adjacent to soffit and eave vents. Baffles should maintain an opening equal or greater than the size of the vent. The baffle should extend over the top of the attic insulation. The baffle should be permitted to be any solid material.

Section R402.2.4/N1102.2.4 Access Hatches and Doors. Any access hatches or doors from conditioned spaces to unconditioned spaces such as attics must also be insulated to a level equivalent to the insulation on the surrounding surfaces (minimum R-30 insulation). In addition the access hatch or door must also be provided with weatherstripping in gaskets to minimize air leakage. Access should be provided to all equipment that prevents damaging or compressing the insulation. A wood-framed or equivalent baffle or retainer is required to be provided when loose-fill insulation is installed, the purpose of which...
is to prevent the loose-fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed R-value of the loose-fill insulation.

Exception: Vertical doors that provide access from conditioned to unconditioned spaces can be permitted to meet the fenestration requirements of Table R402.1.2/N1102.1.2 based upon the applicable climate zone specified in Chapter 3.

Air Sealing/Air Leakage Control

2018/2015 IECC/IRC, R402.4/N1102.4 Air Leakage. The building thermal envelope should be constructed to limit air leakage.

- **Section R402.4.1/N1102.4.1 Building Thermal Envelope.** The sealing methods between dissimilar materials should allow for differential expansion and contraction.
- **Section R402.4.1.1/N1102.4.1.1 Installation.** The components listed in the Air Barrier and Insulation Installation Table (Table R402.4.1.1 of the IECC and Table N1102.4.1.1 of the IRC) should be installed in accordance with the manufacturer’s instructions and the criteria listed as the applicable method of construction. Below are the General Requirements and components from the table that are applicable to sealing and insulating ducts and ceiling assemblies (vented attics).

2018/2015 IRC/IECC, Air Barrier and Insulation Installation Table R402.4.1.1/N1102.4.1.1

- **Continuous air barrier** (defined as a combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope).—Confirms that construction documents specify a continuous air barrier for the building components associated with the insulation of the ceiling (vented attic).
- **Ceiling/attic**—The air barrier in any dropped ceiling/soffit should be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces should be sealed.
- **Shafts/penetrations**—Duct shafts, utility penetrations, and flue shaft openings to the exterior or unconditioned space are sealed.
- **Recessed lighting**—Recessed lighting fixtures installed in the ceiling (vented attic) are sealed to the drywall. The fixtures installed are air tight and IC rated.
- **HVAC register boots**—HVAC register boots that penetrate the ceiling (vented attic) are sealed to the subfloor or drywall.
- **Concealed sprinklers**—When required are sealed, concealed fire sprinklers should only be sealed in a manner that is recommended by the manufacturer. Caulking or other use adhesive sealants should not be used to fill voids between fire sprinkler cover plates and the ceiling.

FIELD INSPECTION:

Per the 2018/2015 IECC, Section R104 Inspections, construction or work for which a permit is required is subject to inspection. Construction or work is to remain accessible and exposed for inspection purposes until approved. (In 2018 IECC, the wording was changed from “accessible” to “visible”.) Required inspections include footing and foundation, framing and rough-in, plumbing rough-in, mechanical rough-in, and final inspection.

**Section R104.2.4 Mechanical Rough-In Inspection.** Inspections at mechanical rough-in shall verify compliance as required by the code and approved plans and specifications as to installed duct system, insulation and corresponding R-values, system air leakage control, and testing. Because the duct system should be installed at the ceiling and then the attic insulation applied over the top of the ducts, this inspection might also include the inspection of the attic sealing and insulation R-values and insulation installation at the same time or performed at final inspection.

In the IRC, Section R109 Inspections, the wording is somewhat different in that for onsite construction the building official, upon notification from the permit holder or his agent, can make, or cause to be made, any necessary inspections. Further details are provided for inspections regarding foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and final inspections. Any additional inspections are at the discretion of the building official.

This section provides details for inspecting to the specific provisions for buried ducts in vented attics where one or more specific type of inspection per the IECC or IRC may be necessary to confirm compliance. Verifying code compliance would typically be at the mechanical rough-in and final inspection.

2018/2015 IECC, Section R303.3.1 Identification. Materials, systems and equipment shall be identified in a manner that will allow determinations of compliance with applicable provisions of the code.

2018/2015 IECC, Section R303.1.1 Building thermal envelope insulation. An R-value identification mark should be applied by manufacturer to each piece of building thermal envelope insulation that is 12 inches or greater in width. Insulation installers should provide a certification that indicates the type, manufacturer and R-value of insulation installed in each element of the building thermal envelope. For blown-in or sprayed fiberglass and cellulose insulation, the initial installed thickness, settled thickness, and settled R-value, installed density, coverage area and number of bags installed should be indicated on the certification. Insulation installer should sign, date, and post the certificate in a conspicuous location on job site.

2018/2015 IECC Section R303.1.1.1 Blown-in or sprayed roof and ceiling insulation. The thickness of blown-in or sprayed fiberglass and cellulose ceiling insulation should be written in inches (mm) on markers that are installed not less than one for every 300 square feet throughout the attic space. Markers should be affixed to the trusses or joists and marked with the minimum initial thickness with numbers not less than 1 inch in height. Markers should face the attic access opening.
Thickness and installed R-value of sprayed polyurethane foam insulation shall be indicated on the certification proved by the insulation installer.

**2018/2015 IECC Section R303.1.1.2 Insulation mark installation.** Insulating materials shall be installed such that the manufacturer’s R-value mark is readily observable at inspections.

**2018/2015 IECC Section R303.1.1.4 Insulation product rating.** Thermal resistance R-value of insulation shall be determined in accordance with Part 460 of US-FTC CFR Title 16.

Inspections should provide verification in the following areas:

- Ductwork: verify all joints and seams in ductwork are properly sealed, and the duct tightness report is complete, verify that duct insulation is installed in accordance with manufacturer’s installation instructions and that the manufacturer’s R-value mark is readily available and meets the approved R-value specified in approved construction documents.

- Ensure proper thickness of duct insulation

- Ensure proper tightness of duct system
  - 1.5 cfm/100ft² if qualifying as in conditioned space
  - 4 cfm/100ft² @ 25Pa if

- Ceiling assembly: verify all joints, seams, holes, and penetrations are caulked, gasketed, weather-stripped, or otherwise sealed.

- Ceiling assembly: ensure that the appearance of the installed ceiling insulation matches that specified in the approved construction documents.

- If the R-value or U-factor approach for compliance was used in the documentation, ensure that the installed insulation meets the minimum R-value or maximum U-factor required for the ceiling and climate zone per the approved construction documents.

- Ensure proper depth of attic insulation

- Ensure a total of R-19 above and/or below the buried ducts

- Ensure that the continuous air barrier is properly installed. Confirm that the air barrier is aligned with the insulation in any dropped ceiling/soffit and sealed.

**Technical Validation/Reference Materials:**

This section provides additional information and helpful resources.


Author(s): ICC
Organization(s): ICC [www.iccsafe.org [4]]
Publication Dates: October 2017 and May 2014

This code establishes 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.


Author(s): ICC
Organization(s): ICC [www.iccsafe.org [4]]
Publication Date: October 2017 and May 2014

This code for residential buildings 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.

- **Compact Buried Ducts in Hot-Humid Climates [7]**
A system of compact, buried ducts provides a high-performance and cost-effective solution for delivering conditioned air throughout the building. This report outlines research activities that are expected to facilitate adoption of compact buried duct systems by builders. The results of this research would be scalable to many new house designs in most climates and markets, leading to wider industry acceptance and building code and energy program approval.

- **Measure Guideline: Buried and/or Encapsulated Ducts** [8]

  Author(s): Shapiro, Zoeller, Mantha  
  Organization(s): CARB  
  Publication Date: August 2013

  Document covering the technical aspects of buried and insulated ducts, as well as the advantages, disadvantages, and risks of buried and insulated ducts compared to alternative strategies.

- **Building America Top Innovations 2013 Profile: Buried and Encapsulated Ducts** [9]

  Author(s): PNNL  
  Organization(s): PNNL  
  Publication Date: September 2013

  Case study providing information about buried and encapsulated ducts.

- **Technology Solutions Case Study: Buried and Encapsulated Ducts, Jacksonville, Florida** [10]

  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.


**BASC Related Guides:**

- Ducts Buried in Ceiling Insulation, [https://basc.pnnl.gov/resource-guides/ducts-buried-ceiling-insulation] [16]


- Duct Leakage to the Outdoors, [https://basc.pnnl.gov/resource-guides/duct-leakage-outdoors] [18]

- Compact Air Distribution, [https://basc.pnnl.gov/resource-guides/compact-air-distribution] [19]

**Plan Review:**

This section lists the applicable code requirements and details helpful for plan review regarding the provisions to meet the requirements for “buried ducts in vented attics in hot-humid and mixed-humid climates.”

Per the **2015 IECC/IRC, Section R103.3/R106.3 Examination of documents**. The code official/building official must examine, or cause to be examined, construction documents for code compliance.
2015 IECC/IRC, Section R103.2/N1101.5 Information on construction documents. Construction documents should include:

- Duct design specifications and layout (refer to Technical Validation/References Section for sources of case studies and example duct designs)
  - Completed ACCA Manual J heating and load calculations. Designers must consider non-typical adjustments for some inputs including duct area, duct leakage, and duct R-value. Current software calculates duct surface area as a percentage of conditioned floor area (depending upon duct layout); therefore, the designer should calculate the actual duct areas for the most accurate results because the duct area will be considerably less than a typical duct layout design. Furthermore, for buried ducts, the required input for the insulation would be the effective R-value. For more information, see Building America research (Shapiro, Zoeller, and Mantha 2013).
  - Section R302.1/N1101.9, Interior Design Conditions. The interior design temperatures used for heating and cooling load calculations should be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.
    - Completed ACCA Manual D for sizing of ducts based on Manual J loads
    - Completed ACCA Manual T for supply and return air registers, size and location
    - Completed ACCA Manual S for correctly sizing mechanical systems.

- Specified R-values of duct insulation (minimum R-8 duct insulation for buried ducts is the recommended and tested best practice, depending on climate zone) and sealant materials.
- Specified R-values of ceiling insulation (ducts covered with a minimum R-30 attic insulation, installed over the top of the ducts, was used at the Building America test house and tested). It should be noted, depending upon the code, location, and climate zone, the minimum R-value for attic insulation could be higher than R-30.
- Air sealing materials and specifications for the buried ducts and ceiling assembly.

Duct System Provisions

2015 IECC/IRC, Section R403.3/N1103.3 Ducts. Ducts and air handlers shall be in accordance with Sections R403.3.1/N1103.3.1 through R403.3.5/N1103.3.5.

- R403.3.1/N1103.3.1 Insulation (prescriptive). Supply and return ducts in attics should 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. (Per the Building America research, a minimum R-8 duct insulation would be required on all buried ducts.)

Exception:

Ducts or portions thereof located completely inside the building thermal envelope. (Buried ducts will be installed outside the building thermal envelope so this exception would not apply.)

- R403.3.2/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 IRC, as applicable.

Exceptions:

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.

- R403.3.2.1/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.

- R403.3.3/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 gauge (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 gauge (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. 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.)

- **R403.3.4/N1103.3.4 Duct Leakage (prescriptive).** The total leakage of the ducts, measured in accordance with Section R403.3.3/N1103.3.3, shall be as follows:

  - **Rough-in test.** The total leakage shall be less than or equal to 4 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 cubic feet per minute (85 L/min) per 100 square feet (9.29 m²) of conditioned floor area.

  - **Post-Construction test.** Total leakage shall be less than or equal to 4 cubic feet per minute (113.3 L/min) per 100 square feet (9.29 m²) of conditioned floor area.

- **R403.3.5/N1103.3.5 Building Cavities (mandatory).** Building framing cavities should not be used as ducts or plenums.

**Building Thermal Envelope Assembly (ceiling provisions)**

**2015 IECC/IRC, Section R402.1.2/N1102.1.2 Insulation Criteria.** The building thermal envelope must meet the requirements of Table R402.1.2/N1102.1.2, based on the climate zone specified in Chapter 3 and the building assemblies associated with the vented attic (ceilings) that are considered part of the building thermal envelope. (Per Building America research, a minimum R-30 attic insulation installed over the top of the ducts would be required.) Again, it should be noted, depending upon the code, location, and climate zone, the minimum R-value for attic insulation could be greater than R-30.

- **2015 IECC/IRC, Section R402.1.3/N1102.1.3 R-Value Computation.** Insulation material used in layers, such as framing cavity insulation, or continuous insulation should be summed to compute the corresponding component R-value. Computed R-values should not include an R-value for other building materials or air films.

- **Excerpt from the 2015 IECC/IRC, Insulation Requirements by Component Table R402.1.2/N1102.1.2**

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 Except Marine</th>
<th>5 and Marine 4</th>
<th>6</th>
<th>7, 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling R-value</td>
<td>30</td>
<td>38</td>
<td>38</td>
<td>49</td>
<td>49</td>
<td>49</td>
<td>49</td>
</tr>
</tbody>
</table>

- **2015 IECC/IRC, Section R402.1.4/N1102.1.4 U-Factor Alternative.** An assembly with a U-factor equal to or less than that specified in Table R402.1.4/N1102.1.4 should be permitted as an alternative to the R-value in Table R402.1.2/N1102.1.2.

- **Excerpt from the 2015 IECC/IRC, Equivalent U-factor Table R402.1.4/N1102.1.4**

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4 Except Marine</th>
<th>5 and Marine 4</th>
<th>6</th>
<th>7, 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling U-factor</td>
<td>0.035</td>
<td>0.030</td>
<td>0.030</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
<td>0.026</td>
</tr>
</tbody>
</table>

- **2015 IECC/IRC, Section R402.2.1/N1102.2.1 Ceilings with attic spaces.** Where Section R402.1.2/N1102.1.2 would require R-38 insulation in the ceiling, installing R-30 over 100% of the ceiling area requiring insulation should be deemed to satisfy the requirement for R-38 wherever the full height of uncompressed R-30 insulation extends over the wall top plate at the eaves. Similarly, where Section R402.1.2/N1102.1.2 would require R-49 insulation in the ceiling, installing R-38 over 100% of the ceiling area requiring insulation should be deemed to satisfy the requirement for R-49 insulation wherever the full height of uncompressed R-38 insulation extends over the wall top plate at the eaves. This reduction should not apply to the U-factor alternative approach described in Section R402.1.4/N1102.1.4.

- **2015 IECC/IRC, Section R402.2.2/N1102.2.2 Ceilings without attic spaces.** Where Section R402.1.2/N1102.1.2 would require insulation levels above R-30 and the roof/ceiling assembly design does not allow sufficient space for the required insulation, the minimum required insulation for such roof/ceiling assemblies should be R-30. This reduction of insulation from the requirements of Section R402.1.2/N1102.1.2 should be limited to 500 square feet or 20% of the total insulated ceiling area, whichever is less. This reduction should not apply to the U-factor alternative approach described in Section R402.1.4/N1102.1.4.
2015 IECC/IRC, Section R402.2.3/N1102.2.3 Eave baffle. For air-permeable insulation in vented attics, a baffle should be installed adjacent to soffit and eave vents. Baffles should maintain an opening equal or greater than the size of the vent. The baffle should extend over the top of the attic insulation. The baffle should be permitted to be any solid material.

2015 IECC/IRC, Section R402.2.4/N1102.2.4 Access Hatches and Doors. Any access hatches or doors from conditioned spaces to unconditioned spaces such as attics must also be insulated to a level equivalent to the insulation on the surrounding surfaces (minimum R-30 insulation). In addition the access hatch or door must also be provided with weatherstripping or gaskets to minimize air leakage. Access should be provided to all equipment that prevents damaging or compressing the insulation. A wood-framed or equivalent baffle or retainer is required to be provided when loose-fill insulation is installed, the purpose of which is to prevent the loose-fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed R-value of the loose-fill insulation.

Exception: Vertical doors that provide access from conditioned to unconditioned spaces can be permitted to meet the fenestration requirements of Table R402.1.2/N1102.1.2 based upon the applicable climate zone specified in Chapter 3.

Air Sealing/Air Leakage Control

2015 IECC/IRC, R402.4/N1102.4 Air Leakage. The building thermal envelope should be constructed to limit air leakage.

- **R402.4.1/N1102.4.1 Building Thermal Envelope.** The sealing methods between dissimilar materials should allow for differential expansion and contraction.

- **R402.4.1.1/N1102.4.1.1 Installation.** The components listed in the Air Barrier and Insulation Installation Table[1] should be installed in accordance with the manufacturer’s instructions and the criteria listed as the applicable method of construction. Below are the General Requirements and components from the table that are applicable to sealing and insulating ceilings (vented attics).

2015 IRC/IECC, Air Barrier and Insulation Installation Table R402.4.1.1/N1102.4.1.1

- **Continuous air barrier[2]** – Confirm that construction documents specify a continuous air barrier for the building components associated with the insulation of the ceiling (vented attic).

- **Ceiling/attic** – The air barrier in any dropped ceiling/soffit should be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stairs or knee wall doors to unconditioned attic spaces should be sealed.

- **Shafts/penetrations** – Duct shafts, utility penetrations, and flue shaft openings to the exterior or unconditioned space are sealed.

- **Recessed lighting** – Recessed lighting fixtures installed in the ceiling (vented attic) are sealed to the drywall. The fixtures installed are air tight and IC rated.

- **HVAC register boots** – HVAC register boots that penetrate the ceiling (vented attic) are sealed to the subfloor or drywall.

- **Concealed sprinklers** – When required, by adopted and enforced code, are sealed, concealed fire sprinklers should only be sealed in a manner that is recommended by the manufacturer. Caulking or other use adhesive sealants should not be used to fill voids between fire sprinkler cover plates and the ceiling.

[1] Table R402.4.1.1 of the IECC and Table N1102.4.1.1 of the IRC.

[2] “Continuous air barrier” in the 2015 IECC is defined as a combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

Field Inspection:

Per the 2015 IECC, Section R104 Inspections, construction or work for which a permit is required is subject to inspection. Construction or work is to remain accessible and exposed for inspection purposes until approved. Required inspections include footing and foundation, framing and rough-in, plumbing rough-in, mechanical rough-in, and final inspection.

**R104.2.4 Mechanical Rough-In Inspection.** Inspections at mechanical rough-in shall verify compliance as required by the code and approved plans and specifications as to installed duct system, insulation and corresponding R-values, system air leakage control, and testing. Because the duct system should be installed at the ceiling and then the attic insulation applied over the top of the ducts, this inspection might also include the inspection of the attic sealing and insulation R-values and insulation installation at the same time or performed at final inspection.
In the **IRC, Section R109 Inspections**, the wording is somewhat different in that for onsite construction the building official, upon notification from the permit holder or his agent, can make, or cause to be made, any necessary inspections. Further details are provided for inspections regarding foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and final inspections. Any additional inspections are at the discretion of the building official.

This section provides details for inspecting to the specific provisions for buried ducts in vented attics where one or more specific types of inspection per the IECC or IRC may be necessary to confirm compliance. Verifying code compliance would typically be at the mechanical rough-in and final inspection.

Inspections should provide verification in the following areas:

- Verify that joints and seams in ductwork are properly sealed, and the duct tightness report is complete and has been submitted per jurisdictional requirements. If ducts are employed, verify that duct insulation is installed in accordance with manufacturer’s installation instructions and that the manufacturer’s R-value mark is readily available and meets the approved R-value specified in construction documents.
- Verify that joints, seams, holes, and penetrations are caulked, gasketed, weather-stripped, or otherwise sealed.
- Ensure that the appearance of the installed ceiling insulation matches that specified in the approved construction documents.
- If the R-value or U-factor approach for compliance was used in the documentation, ensure that the installed insulation meets the minimum R-value or maximum U-factor required for the ceiling and climate zone per the approved construction documents.
- Ensure that the continuous air barrier is properly installed. Confirm that the air barrier is aligned with the insulation in any dropped ceiling/soffit and sealed.

**Technical Validation(s):**

This section provides additional information and helpful resources.

- **Measure Guideline: Buried and/or Encapsulated Ducts** [8]

  Author(s): Shapiro, Zoeller, Mantha
  Organization(s): CARB
  Publication Date: August 2013

  Document covering the technical aspects of buried and insulated ducts, as well as the advantages, disadvantages, and risks of buried and insulated ducts compared to alternative strategies.

- **Building America Top Innovations 2013 Profile: Buried and Encapsulated Ducts** [9]

  Author(s): PNNL
  Organization(s): PNNL
  Publication Date: September 2013

  Case study providing information about buried and encapsulated ducts.

- **Technology Solutions Case Study: Buried and Encapsulated Ducts, Jacksonville, Florida** [10]

  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.

- **Compact Buried Ducts in Hot-Humid Climates** [7]

  Author(s): D Mallay
  Organization(s): Home Innovation Research Labs
  Publication Date: January 2016
A system of compact, buried ducts provides a high-performance and cost-effective solution for delivering conditioned air throughout the building. This report outlines research activities that are expected to facilitate adoption of compact buried duct systems by builders. The results of this research would be scalable to many new house designs in most climates and markets, leading to wider industry acceptance and building code and energy program approval.


BASC Related Guides:
- Ducts Buried in Attic Insulation and Encapsulated, [21] https://basc.pnnl.gov/resource-guides/ducts-buried-attic-insulation-and...
- Duct Leakage to the Outdoors, [18] https://basc.pnnl.gov/resource-guides/duct-leakage-outdoors