Scope

Install Insulating sheathing above the roof deck on existing homes. This retrofit assembly is appropriate for homes with conditioned attics or where the retrofit is intended to create a conditioned attic.

A. Remove existing roofing and non-adhered underlayment to expose roof sheathing.

B. Apply continuous air control membrane to existing roof sheathing or implement continuous air control at roof sheathing.

C. Install rigid insulation board in multiple layers with joints offset vertically and horizontally between adjacent layers. Rigid insulation layers exterior to existing roof sheathing must provide sufficient thermal insulation (R-value) to control condensation risk (see climate specific guidance).

D. Install nailbase for cladding. Nailbase must be vented in high snow-load areas.

E. Install roofing underlayment, flashing, and cladding as per best practices. See Step and kick-out flashing at roof-wall intersections, extending ≥ 4” on wall surface above roof deck and integrated with drainage plane, and Self-sealing bituminous membrane or equivalent at all valleys & roof deck penetrations.

F. Install cavity insulation (e.g. netted fibrous insulation, batt insulation) to achieve desired total assembly R-value. See Insulation Installation (RESNET Grade 1)

See the Building America Solution Center guide on Pre-Retrofit Assessment of Attics, Ceilings, and Roofs for more information.

The U.S. Department of Energy’s Standard Work Specifications has additional information on above roof deck insulation.

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

Air Control Membrane

The existing roof cladding as well as non-adhered underlayment must be removed in order to allow an air control membrane to be installed or established at the roof deck. Robust air control is essential for a high performance enclosure. An air control membrane is needed below the insulating sheathing to prevent moisture-laden air from migrating through the joints in the insulating sheathing. With the right materials and detailing, the air control membrane can also provide temporary water protection and permanent back-up water protection.

There are three options for an air control membrane installed on top of the roof sheathing these are listed relative to air control and temporary/back-up water control performance:

**Good** – Non-adhered roof underlayment made air tight with taped seams and air tight connections to the air control of adjacent assemblies. Make sure all seams are properly lapped.

**Better** – Self-adhered air and water control membrane. Because of the insulation exterior, the product may not need to be specifically designated for roof applications, however, traction on steep slopes must be a priority consideration as it relates to workers’ safety. Make sure all seams are properly lapped.

**Best** – Fully-adhered, self-sealing ice and water control membrane, installed shingle style.

If the existing roof sheathing is made up of wood sheathing panels (plywood or OSB) the air control membrane can also be established at the roof sheathing by taping the joints between sheathing panels.

Above Deck Insulation

The insulation installed over the roof deck must be installed in multiple layers with joints offset in order to control convective looping at joints between insulation panels.

Materials appropriate for insulating sheathing with unvented cladding substrate include:

- Polyisocyanurate,
- Extruded polystyrene (XPS),
- Expanded polystyrene (EPS) type II, and
- Semi-rigid mineral fiber insulation boards PROVIDED the material has adequate compressive strength. Mineral fiber with compressive strength of 0.625 psi at 10% deformation has been shown to work in wall systems where 1x4 furring strips are installed over the insulation.

In a configuration with a vented cladding substrate (such as used for ice dam protection in high snow load areas), the outer layer of insulating sheathing must be detailed as a drainage plane. Therefore, it must have surfaces that provide a suitable substrate for flashing or sheathing tapes. More information on using insulating sheathing as a drainage plane is available in the Taped Insulating Sheathing Drainage Planes Guide. Insulation materials appropriate for the outer layer of insulating sheathing include:

- XPS or
- Foil-faced polyisocyanurate.

Roof Cladding Substrate

An unvented roof cladding substrate (e.g. plywood or OSB roof sheathing) can be installed over exterior insulation layers using long exterior-grade screws. The screws must be long enough to penetrate an adequate depth into the roof framing. Marking the location of framing on successive layers is very important in locating the framing particularly when the framing has irregular spacing.

If purlins are used to create a vented over-roof, the purlins are fastened to the framing through the insulating sheathing. The substrate for the roof cladding is then fastened to the purlins much as it would be fastened to a new roof. Gaps along the length of the purlins can provide cross ventilation such as would be necessary to effectively vent a roof with hips, valleys or other obstructions to the soffit-to-ridge ventilation space. Large gaps in the purlins must be coordinated with the nailing pattern for the cladding substrate.

Once the substrate for the roof cladding is installed, installation of roofing underlayment, flashing, and cladding follows best practices. See Step and Kick-Out Flashing at Roof-Wall Intersections, extending ? 4” on wall surface above roof deck and integrated with drainage plane, and Self-sealing bituminous membrane or equivalent at all valleys & roof deck penetrations.

Cavity Insulation

Installation of cavity insulation follows typical best practices. See Insulation Installation (RESNET Grade 1). Note that too much insulation installed to the interior can upset the condensation control of the assembly.

If installing closed-cell spray foam or other low permeance insulation to the interior, it is very important to verify that the roof
sheathing and framing are dry (e.g. 12-15% moisture content or less) before installing cavity insulation. It is also a good idea to verify that sheathing and wood framing are dry before installing any kind of cavity insulation.

It is generally best to install cavity insulation only after the new exterior water management system is installed. However, in certain circumstances, it may be desirable and necessary to install cavity insulation from the exterior. The risk that must be managed is water penetration to the roof sheathing or cavity insulation after installation of cavity insulation. Although a properly designed assembly will be able to control the condensation risk of diffusion or air transported moisture, the insulation to the interior of the roof sheathing will inhibit the ability of the assembly to dry if a bulk water leak occurs. The system is more vulnerable to leaks between the time that the existing roofing is removed and new water control systems are installed. If water leaks into the assembly after insulation is installed, the insulation must be removed, the source of the leak identified and corrected, and the sheathing and framing allowed to dry thoroughly (e.g. 12-15% moisture content) before cavity insulation is replaced.

Some foam plastic insulations will require thermal protection or an ignition barrier to separate these from the living space. Consult the manufacturer of the insulation material and the local building code to learn of specific requirements.

**How to Retrofit a Roof to a High Performance Roof with Insulating Sheathing above the Roof Deck Plus Cavity Insulation in Roof Framing**

1. Remove existing roofing and non-adhered roof underlayment.
2. Apply a continuous air control membrane to existing roof sheathing -OR- Tape all joints between roof sheathing panels with an acrylic or butyl adhesive flashing tape/membrane.
3. Mark the location of framing on the air control membrane to facilitate attachment of roofing substrate or purlins.
4. Seal around any penetrations through the air control layer. If the air control layer is to provide water control, provide proper flashing as well as air sealing for penetrations.
5. Install rigid insulation board over the air control layer in multiple layers with joints offset vertically and horizontally between adjacent layers.

**IF PROVIDING A VENTED OVER-ROOF**

Detail the outer layer of the insulating sheathing as a drainage plane.

6. Transfer the markings for framing locations through each layer of insulating sheathing.
7. Install substrate for cladding -OR- Install purlins and cladding substrate.
8. Install roof underlayment, flashing and cladding as per best practices. See [Step and kick-out flashing at roof-wall intersections](#), extending 4" on wall surface above roof deck and integrated with drainage plane, and [Self-sealing bituminous membrane or equivalent at all valleys & roof deck penetrations](#).
9. Install cavity insulation (netted fibrous insulation, batt insulation, spray foam insulation) to achieve desired total assembly R-value. See [Insulation Installation (RESNET Grade 1)](#).
Ensuring Success

Exterior insulation permits high R-value to be achieved without necessarily disturbing interior finishes. The best time to implement this approach from a cost perspective is when an existing roof is being replaced.

Important health and safety prerequisites for high-performance enclosure retrofits

This high-performance retrofit measure is likely to have a significant impact on the dynamics of air, vapor and heat flow within the home. Certain measures must be implemented to ensure that these changing dynamics do not have negative ramifications for health and safety. It is also necessary to ensure that parts of the building not directly affected by the work are able to support and protect the planned work.

Prior to implementing a high-performance roof retrofit assembly it is important to do the following:

- Ensure combustion safety for combustion equipment located within the pressure boundary.
- Remediate any hazardous conditions that will be affected (e.g. exposed or aggravated) by the planned work.
- Ensure that the roof system provides robust protection from rain water and ice dams and that proper flashing is in place. Note that the retrofit measure featured in this guide includes installation of new roofing. Implementation of effective roof water management is taken to be part of this measure. Also ensure that the roof structure is adequate to support any additional load that may be added.
- Provide mechanical ventilation if not already provided.

Combustion safety

Provide minimum combustion safety by providing direct-vent sealed-combustion equipment or forced draft equipment (see Direct Vent Equipment). When furnaces, boilers, and water heaters are installed within the home’s pressure boundary, ideally this equipment would be direct-vent sealed-combustion equipment. If existing equipment is not direct-vent sealed-combustion or forced draft, the homeowners must decide whether to:

- replace equipment with direct vent or forced draft equipment, or
- retrofit forced-draft to existing equipment.

Providing make up air through passive inlets is not compatible with high-performance objectives.

Hazardous materials

Hazardous materials that will be affected by the retrofit work or that may impact the indoor air quality must be remediated and/or removed. Examples of hazardous materials that may be found in attic/roof assemblies of existing structures include (but are not limited to) lead, asbestos, animal dropping/remains, etc. Items stored in an attic space may also present potential hazards. Follow applicable laws and industry procedures for mitigation of hazardous materials. Engage the services of a qualified professional when needed.

Roof condition

A structural evaluation may be needed to determine if the roof is capable of supporting expected snow loads above a high R-value attic/roof assembly. Engage the services of a qualified professional when needed.

Ventilation

Provide whole-house and local exhaust (source control) mechanical ventilation complying with Section M1507 of the 2012 International Residential Code. Providing mechanical ventilation may be implemented concurrent with or as part of the larger attic/roof retrofit project.

Performance imperatives for high R-value roof retrofit using insulating sheathing above the roof deck plus cavity insulation in roof framing

The following measures are necessary to ensure high levels of performance for this roof retrofit strategy.

Rain water control

Effective water control is essential to the performance of any attic/roof system. Because this strategy involves exterior insulation and “over-roofing” it presents the opportunity to establish a robust water control system at the roof. The water control for a sloped roof includes a rain shedding cladding (e.g. asphalt shingles), a water control layer such as roofing underlayment that is impervious to liquid water, and flashing that is integrated with the water control layer. See Step and kick-out flashing at roof-wall intersections, extending ≥ 4” on wall surface above roof deck and integrated with drainage plane, and Self-sealing bituminous membrane or equivalent at all valleys & roof deck penetrations.

It may be obvious but is worth noting that temporary rain water control will be needed during construction. The air control membrane installed over the existing sheathing may be able to provide temporary rain water control if it is a water impermeable material and is appropriately detailed.
Air control

Effective air control is essential to the thermal performance of this measure as well as to condensation control. In this retrofit assembly the air control membrane is installed directly above the existing roof deck and below insulating sheathing. The air control membrane must be connected in a continuous manner to the air control membrane of adjacent assemblies.

Condensation control

If vapor permeable or air permeable insulation is used in the roof framing below the roof deck, then the insulation above the roof deck must be sufficient to control condensation risk at the roof sheathing. Table R806.5 in the 2012 IRC (R806.4 in the 2009 IRC) indicates the amount of insulation above the roof deck required for condensation control assuming minimum required total insulation. High R-value unvented roof assemblies will require a proportionally larger amount of insulation above the roof deck for condensation control. Generally, 40% of the total assembly R-value should be above the roof deck. More insulation is needed above the roof deck in colder climates and where indoor relative humidity is above ~35% in winter. See BSD-163: Controlling Cold Weather Condensation Using Insulation.

In roof assemblies with deep roof framing cavities that make it difficult to limit the amount of insulation below the roof deck, large amounts of insulation may be required above the roof deck in order to control condensation.

Dry sheathing

Protect the structure during construction. Especially in climates where rain is a common occurrence, it is a good idea to detail the air control layer installed over the existing roof sheathing as a temporary water control layer.

Insulation installed to the interior of the roof deck will reduce the ability of the roof deck to dry to the interior. The exterior water management must be fully implemented and verified before roof cavity insulation is installed. Any roof sheathing or framing that was exposed to water during construction must be allowed to dry thoroughly before installation of insulation (e.g. to a moisture content of 12%). Use a moisture meter to verify wood moisture content below 12% prior to installing closed-cell insulation or other vapor impermeable or semi-vapor impermeable insulation to the interior side of the roof deck.

Thermal protection

Unless the manufacturer has obtained appropriate approvals for the product, foam plastic insulations used inside the attic will require a thermal protection or ignition barrier covering. Gypsum wall board can provide appropriate thermal protection. Intumescent paints may be compatible with some foam plastic products. Typically the combination of specific intumescent paint and foam plastic insulation product will have to have been tested and approved.

Connection to adjacent assemblies

The thermal control of a high R-value roof retrofit can be bypassed if the assembly is not properly connected to thermal control at the walls. If a gabled attic is to be brought into the thermal enclosure, the gable walls will need to be insulated as well. The connection between the roof assembly and wall assembly is critical for air control.

Making the Contractor’s Life Easier

Mark the location of framing on successive layers so that workers can more easily hit framing with fasteners when needed. It is especially important to keep track of framing locations in retrofit because the framing may have irregular spacing.
Climate

Recommended high R-value levels are indicated in Table 1 below and shown relative to 2012 IRC/IECC prescriptive requirements.

### Table 1. Code Requirements and High R-Value Targets

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>2012 IRC/IECC Prescriptive Requirements</th>
<th>High R-Value Target</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vented Attic</td>
<td>Compact Roof*</td>
</tr>
<tr>
<td>1</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>38</td>
<td>30</td>
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<tr>
<td>8</td>
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</tbody>
</table>

### Insulation for condensation control

Insulation above the roof deck or air/vapor impermeable insulation below the roof deck is needed for condensation control in an unvented roof. The ratio of insulation above the roof deck or air permeable insulation below the roof deck is a matter of climate and interior conditions. Generally, more insulation is needed for condensation control in colder climates. Also, the higher the indoor humidity, the more insulation is needed to avoid condensation.

The chart below illustrates the amount of insulation relative to total insulation that is needed to control condensation. This chart is adapted from “Controlling Cold-Weather Condensation Using Insulation” (Straube 2011). The insulation controlling condensation can be entirely above the roof deck, or it can be air and vapor impermeable insulation below the roof deck, or it can be a combination of insulation above the roof deck and air/vapor impermeable insulation below the roof deck.

![Ratio of Exterior-Total Insulation to Control Air Leakage Condensation](chart_image.png)

**Figure 1.** Insulation for condensation control from “Controlling Cold-Weather Condensation Using Insulation”

### Ventilated over-roof

In regions with greater than 50 pounds per sf ground snow load the roof cladding substrate must be vented to prevent ice damming. The substrate or nailbase is attached to purlins installed over the top of the exterior insulation to create a ventilation cavity. The ventilation cavity must be 2” clear between the cladding substrate and exterior insulation (Lstiburek 2006). The cavity between purlins is vented by a ventilation opening at the bottom (eave) and at the top (ridge) – if the ventilation cavity cannot be connected directly to both a soffit and ridge vent, then the purlins must be made discontinuous to allow crossflow.

With the ventilated over-roof approach, the top of the exterior insulation should be detailed as a drainage plane to allow incident water to be drained from the system.
Figure 2. Schematic of exterior insulated roof assembly with vented cladding substrate from Mass Save Deep Energy Retrofit Builder Guide
Training

Right and Wrong Images
None Available
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.

2009 - 2018 IECC and IRC Minimum Insulation Requirements: The minimum insulation requirements for ceilings, walls, floors, and foundations in new homes, as listed in the 2009, 2012, 2015, and 2018 IECC and IRC, can be found in this table.

2009 IECC

Section 101.4.3 Additions, alterations, renovations or repairs. Portions of an existing building that are altered in the course of additions, alterations, renovations or repairs must be brought into conformance with the code with the following exceptions applicable to attic/roof retrofit: existing ceiling wall or floor cavities that are exposed provided the cavities exposed are filled with insulation; addition, alteration, renovation or repair projects that do not expose the existing roof, wall or floor cavity; reroofing that does not expose the insulation nor the sheathing.

Section 101.4.5 Change in space conditioning. This section states that spaces must be brought into full compliance with the new construction requirements if the addition, alteration, renovation or repair changes that space from unconditioned to conditioned space.

Section 402 Building Thermal Envelope. Table 402.1.1 indicates the prescriptive requirements for building enclosure components.

Section 402.2.2 Ceilings without attic spaces. Where the prescriptive requirements would require more than R-30 insulation but the roof/ceiling configuration cannot accommodate the insulation level indicated by the prescriptive requirements, R-30 is the minimum insulation requirement. This reduced insulation requirement is limited to the lesser of 500 square feet or 20% of the total insulated ceiling area. Note that assemblies achieving high R-value by insulating to the exterior of the sheathing and in the roof framing cavities should not need to use these exceptions.

Section 402.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IECC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

2012, 2015, and 2018 IECC

Section R101.4.3 (R501.1.1 adn 503.1.1 in 2015 and 2018 IECC) Additions, alterations, renovations or repairs. Portions of an existing building that are altered in the course of additions, alterations, renovations or repairs must be brought into conformance with the code with the following exceptions applicable to attic/roof retrofit: existing ceiling wall or floor cavities that are exposed provided the cavities exposed are filled with insulation; addition, alteration, renovation or repair projects that do not expose the existing roof, wall or floor cavity; reroofing that does not expose the insulation nor the sheathing.

Section R101.4.5 (R503.2 in 2015 and 2018 IECC) Change in space conditioning. This section states that spaces must be brought into full compliance with the new construction requirements if the addition, alteration, renovation or repair changes that space from unconditioned to conditioned space.

Section R402 Building Thermal Envelope. Table R402.1.1 (Table R402.1.2 in 2015 and 2018 IECC) indicates the prescriptive requirements for building enclosure components.

Section R402.2.2 Ceilings without attic spaces. Where the prescriptive requirements would require more than R-30 insulation but the roof/ceiling configuration cannot accommodate the insulation level indicated by the prescriptive requirements, R-30 is the minimum insulation requirement. This reduced insulation requirement is limited to the lesser of 500 square feet or 20% of the total insulated ceiling area. Note that assemblies achieving high R-value by insulating to the exterior of the sheathing and in the roof framing cavities should not need to use these exceptions.

Section R402.2.3 Eave baffle. This section indicates the requirement for baffles to be installed next to eave and soffit vents for vented attics using air permeable insulations. The baffle can be any solid material, must extend to the top of the attic insulation, and must maintain an opening that is at least as large as the vent. Note that baffles should also be used with vented over-roof assemblies that use air permeable insulations.

Section R402.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IECC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

2009 IRC

Appendix J, Section 501.6, Ventilation. The appendix is not attached to the requirements of the IRC unless it is specifically included by the adopting jurisdiction. This section of the appendix indicates that any space that is changed to be habitable or occupiable by alteration must be provided with ventilation in accordance with Section R303.

Section R806.3 Vent and insulation clearance. A vent space clearance of at least 1” must be maintained at the location of the vent and between insulation and roof sheathing. Note that this would not apply where an unvented roof assembly is used as indicated in section R806.4 unless the cladding substrate above the insulation is vented (as is necessary in locations with greater than 50 psf ground snow load). Effective performance of the vent space requires a clearance of 2” or more.

Section R806.4 Unvented attic assemblies. This section outlines the conditions for unvented attic/roof assemblies. Note that table R806.4 indicates the amount of insulation above the roof deck or air impermeable insulation below the roof deck required for condensation control assuming minimum required total insulation as indicated in Section N1102 Building Thermal Envelope.
Higher R-value assemblies will require a proportionally larger amount of air impermeable insulation below the roof deck or insulation above the roof deck for condensation control.

Section R807.1 Attic access. An attic access is required where the ceiling or roof construction is combustible and where the attic area is more than 30 sf and the height between the ceiling framing and roof framing is more than 30”. Refer to specific language of this section for required dimensions of the access.

Section N1102 Building Thermal Envelope. Table N1102.1 indicates the prescriptive requirements for building enclosure components.

Section N1102.2.2 Ceilings without attic spaces. Where the prescriptive requirements would require more than R-30 insulation but the roof/ceiling configuration cannot accommodate the insulation level indicated by the prescriptive requirements, R-30 is the minimum insulation requirement. This reduced insulation requirement is limited to the lesser of 500 square feet or 20% of the total insulated ceiling area. Note that assemblies achieving high R-value by insulating to the exterior of the sheathing and in the roof framing cavities should not need to use these exceptions.

Section N1102.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IRC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.

Appendix J, Section 501.6, Ventilation. The appendix is not attached to the requirements of the IRC unless it is specifically included by the adopting jurisdiction. This section of the appendix indicates that any space that is changed to be habitable or occupiable by alteration must be provided with ventilation in accordance with Section R303.

Section R806.3 Vent and insulation clearance. A vent space clearance of at least 1” must be maintained at the location of the vent and between insulation and roof sheathing. Note that this would not apply where an unvented roof assembly is used as indicated in section R806.5 unless the cladding substrate above the insulation is vented (as is necessary in locations with greater than 50 psf ground snow load). Effective performance of the vent space requires a clearance of 2” or more.

Section R806.4 Installation and weather protection. This section indicates that ventilators for roofs are to be installed in accordance with manufacturer’s installation instructions and the requirements of Section R903.

Section R806.5 Unvented attic assemblies. This section outlines the conditions for unvented attic/roof assemblies. Note that table R806.5 indicates the amount of insulation above the roof deck or air impermeable insulation below the roof deck required for condensation control assuming minimum required total insulation as indicated in Section N1102 Building Thermal Envelope. Higher R-value assemblies will require a proportionally larger amount of air impermeable insulation below the roof deck or insulation above the roof deck for condensation control.

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Section N1102 Building Thermal Envelope. Table N1102.1.1 (Table N1102.1.2 in 2015 and 2018 IRC) indicates the prescriptive requirements for building enclosure components.

Section N1102.2.2 Ceilings without attic spaces. Where the prescriptive requirements would require more than R-30 insulation but the roof/ceiling configuration cannot accommodate the insulation level indicated by the prescriptive requirements, R-30 is the minimum insulation requirement. This reduced insulation requirement is limited to the lesser of 500 square feet or 20% of the total insulated ceiling area. Note that assemblies achieving high R-value by insulating to the exterior of the sheathing and in the roof framing cavities should not need to use these exceptions.

Section N1102.2.3 Eave baffle. This section indicates the requirement for baffles to be installed next to eave and soffit vents for vented attics using air permeable insulations. The baffle can be any solid material, must extend to the top of the attic insulation, and must maintain an opening that is at least as large as the vent. Note that baffles should also be used with vented over-roof assemblies that use air permeable insulations.

Section N1102.4 Air Leakage. This section indicates that the building thermal envelope (as it is called in the IRC) must be sealed to limit infiltration and that it must be sealed in a manner that is durable allowing for differential expansion and contraction.


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.

Controlling Moisture in Unvented Attics - Code Compliance Brief

Overview:

The intent of this brief is to provide code-related information about controlling moisture in unvented attics by installing a vapor diffusion port/vent that would convey water vapor from an unvented attic to the outside when air-permeable insulation materials are installed and can be verified as being in compliance with the related codes and standards for residential construction. Providing consistent information to document compliance with codes and standards to all relevant parties
responsible for verifying compliance (e.g., code officials, builders, contractors, designers, etc.) is expected to result in increased compliance and more timely, less challenging and more uniform plan review and field inspections.

In the early 1990s, construction of unvented attics became popular, especially for structures in warmer climates. The typical construction scenario involved the use of low-density, open-cell spray foam insulation for the thermal barrier at roof deck and duct work installed in the unvented attic space. Most of these attics stayed dry. “These were conditioned attics,” said Joe Lstiburek, Building Science Corporation, CEO. [1] “The conditioning was happening because of leaky ductwork. The supply ducts were leaking, and there was a leaky ceiling.” The attics were accidentally heated during the winter and accidentally cooled during the summer by air escaping through cracks in the duct seams. This type of conditioning kept attic moisture levels under control. Lstiburek continued, “Later, when the ductwork got tighter, we ended up with very high humidity in the attics, and we discovered sweating on the ducts and mold on the mastic.”

In summary, Lstiburek’s explanation was that moisture in the attic originated inside the house. Moisture ended up in the attic rather than in the lower floors of the house through a phenomenon known as “hygric buoyancy.” This phenomenon occurs when moisture-laden air is lighter and less dense than dry air so the moisture-laden air collects in the attic.

After Dr. Lstiburek identified this moisture problem, further investigation revealed what the recent codes addressed or did not address and whether or not the codes needed to be changed. The study revealed that proper moisture, ventilation, and insulation requirements in climate zones 1, 2, and 3 for unvented attics and unvented enclosed rafter assemblies are not addressed in the 2015 International Energy Conservation Code (IECC). These measures are identified as code barriers because they are neither discouraged nor encouraged by the recent model codes (i.e., IECC). Moisture, ventilation, and insulation requirements are addressed for unvented attics in the International Residential Code (IRC), but only for air-impermeable insulation [2] or rigid board insulation installed above roof decks.

Through the Building America Program, new approaches have successfully been researched and validated. The Building America research team, Building Science Corporation, submitted separate proposals for the 2018 International Code Council (ICC) code hearings to address the moisture, ventilation, and insulation issues in unvented attics with interior insulation. The code proposals include new language about installing a vapor diffusion port or rigid board insulation installed above roof decks.

The next section of this Code Compliance Brief lists applicable code requirements and details helpful for Plan Review. The Field Inspection section that follows provides details regarding the inspection of unvented attics and unvented enclosed rafter assemblies. Refer to the last section of this brief for resources on technical validation, best practices, and measure guidelines.

These lists and provisions provided below in each section are intended to target the main code sections and provisions. There may be other references, code sections, standards, testing methods, etc., that affect the technology or other assemblies or functions of the building.


[2] Air-impermeable insulation is defined in the 2015 IRC as an insulation having an air permanence equal to or less than 0.02 L/s·m² at 75 Pa pressure differential as tested in accordance with ASTM E 2178 or E 283.

Plan Review:

This section, provides current code sections and details in the 2015 IRC and IECC, and the language (underscored, struck-through, and highlighted in red) from code change proposals that were approved for the 2018 IRC.
2015 IRC, Section R104 Duties and Powers of the Building Official

Section R104.1, General. The building 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.

2015 IECC/IRC, Section R102.1/R104.11, Alternative Materials, Design and Method of Construction and Equipment. The provisions of this code are not intended to prevent the installation of any material or prohibit any design or method of construction not specifically prescribed in the 2015 IECC/IRC, provided that any such alternative has been approved. The building official is permitted to approve an alternative material, design, or method of construction where the building official 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, not less than the equivalent of that prescribed in the code. Compliance with specific performance-based provisions of the International Codes is an alternative to the specific requirements of this code.

2015 IRC, 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 building official has authority to require tests as evidence of compliance to be made at no expense to the jurisdiction. Test methods shall be as specified in this code or by other recognized test standards. In the absence of recognized and accepted test methods, the building official shall approve the testing procedures. Tests shall be performed by an approved agency. Reports of such tests shall be retained by the building official for the period required for retention of public records.

Construction Documentation. Review the construction documents for details describing roof ventilation, attic insulation, installation, air sealing, and construction techniques. (Bullet items underscored are based on the 2018 ICC code proposals.)

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 be of sufficient clarity to indicate the location, nature, extent of the work proposed, and show of sufficient detail pertinent data features. (Bullet items below that are underscored and highlighted in red are based on the new provisions that will be published in the 2018 IRC. Construction documents should include:

- Roof assembly details.
- **Vapor diffusion port(s)/vent(s)** design and location.
- Moisture barrier material used for the vapor diffusion port(s)/vent(s).
- Insulation materials and their R-values.
- Details indicating how the insulation is to be applied.
- Where preformed insulation board is used as the air-impermeable insulation layer, confirm that the construction documents specify air sealing at the perimeter of each individual sheet interior surface to form a continuous layer.
- Air sealing details (joints, seams, penetrations).
- Confirm that the continuous air barrier is specified.
- Details of roof ventilation and moisture control.
- Design specifications of air supplied to the conditioned attic.

2015 IRC, Section R202, Definitions

**Vapor Diffusion Port.** A passageway for conveying water vapor from an unvented attic to the outside atmosphere.

Section R806.5, Unvented attic and unvented enclosed rafter assemblies. Unvented attics and unvented enclosed roof framing assemblies created by ceilings that are applied directly to the underside of the roof framing members and structural roof sheathing applied directly to the top of the roof framing members/rafters, shall be permitted where all the following conditions are met:

1. The unvented attic space is completely within the building thermal envelope. [3]
2. No interior Class I vapor retarders are installed on the ceiling side (attic floor) of the unvented attic assembly or on the ceiling side of the unvented enclosed roof framing assembly.
3. Where wood shingles or shakes are used, a minimum ¼-inch (6.4 mm) vented airspace separate the shingles or shakes and the roofing underlayment above the structural sheathing.
4. In climate zones 5, 6, 7, and 8, any \textit{air-impermeable insulation} shall be a Class II vapor retarder, or shall have a Class II vapor retarder coating or covering in direct contact with the underside of the insulation.

5. Insulation shall be located in accordance with the following with \textit{comply} with either 5.1 or 5.2, and additionally 5.3:

5.1. Item 5.1.1, 5.1.2, 5.1.3, or 5.1.4 shall be met, depending on the air permeability of the insulation directly under the structural roof sheathing.

5.1.1. Where only \textit{air-impermeable insulation} is provided, it shall be applied in direct contact with the underside of the structural roof sheathing.

5.1.2. Where \textit{air-permeable insulation} is provided inside the building thermal envelope, it shall be installed in accordance with Section 5.1. In addition to the \textit{air-permeable insulation} installed directly below the structural sheathing, rigid board or sheet insulation shall be installed directly above the structural roof sheathing in accordance with the \textit{R}-values in Table R806.5 for condensation control.

5.1.3. Where both \textit{air-impermeable} and \textit{air-permeable insulation} are provided, the \textit{air-impermeable insulation} shall be applied in direct contact with the underside of the structural roof sheathing in accordance with Item 5.1.1 and shall be in accordance with the \textit{R}-values in Table R806.5 for condensation control. The \textit{air-permeable insulation} shall be installed directly under the \textit{air-impermeable insulation}.

5.1.4. Alternatively, sufficient rigid board or sheet insulation shall be installed directly above the structural roof sheathing to maintain the monthly average temperature of the underside of the structural roof sheathing above 45°F (7°C). For calculation purposes, an interior air temperature of 68°F (20°C) is assumed, and the exterior air temperature is assumed to be the monthly average outside air temperature of the three coldest months.

5.1.5. In climate zones 1, 2, and 3 air shall be supplied at a flow rate \(\geq 50\) CFM (23.6 L/s) per 1000 ft\(^2\) of ceiling. The air shall be supplied from ductwork providing supply air to the occupiable space when the conditioning system is operating. Alternatively one of the following shall occur:

1. Air shall be supplied to the attic by a fan blowing air from the occupiable space into the attic.

2. Transfer air from the occupiable space shall be provided by a fan exhausting attic air to the outside.

3. Mechanical dehumidification shall be provided to the unvented attic air space.

5.2. In climate zones 1, 2, and 3 when \textit{air-permeable insulation} is installed in unvented attics, it shall meet the following requirements:

1) An \textit{approved vapor diffusion port} shall be installed not more than 12 inches (305 mm) from the highest point of the roof, measured vertically from the highest point of the roof to the lower edge of the port.

2) The port area shall be \(\geq 1.600\) of the ceiling area. Where there are multiple ports in the attic, the sum of the port areas shall be greater than or equal to the area requirement.

3) The vapor permeable membrane in the \textit{vapor diffusion port} shall have a vapor permeance rating of \(\geq 20\) perms when tested in accordance with Procedure A of ASTM E96.

Confirm the vapor permeable membrane product specifications have been tested and rated accordingly.

4) The \textit{vapor diffusion port} shall serve as an \textit{air barrier} between the attic and the exterior of the building.

5) The \textit{vapor diffusion port} shall protect the attic against the entrance of rain and snow.

6) Framing members and blocking shall not block the free flow of water vapor to the port. Not less than a 2-inch (50-mm) space shall be provided between any blocking and the roof sheathing. Air-permeable insulation shall be permitted within that space.

7) The roof slope shall be \(\geq 3:12\) (vertical/horizontal).

8) Where only \textit{air-permeable insulation} is used, it shall be installed directly below the structural roof sheathing.

9) \textit{Air-impermeable insulation}, if any, shall be directly above or below the structural roof sheathing and is not required to meet the \textit{R}-value in in Table 806.5. When directly below the structural roof sheathing, there shall be no space between the air-impermeable and air-permeable insulation.

10) The air shall be supplied at a flow rate \(\geq 50\) CFM (23.6 L/s) per 1000 ft\(^2\) of ceiling. The air shall be supplied from ductwork providing supply air to the occupiable space when the conditioning system is operating. Alternatively, the air shall be supplied by a supply fan when the conditioning system is operating.
5.3. Where preformed insulation board is used as the air-impermeable insulation layer, it shall be sealed at the perimeter of each individual sheet interior surface to form a continuous layer.

Excerpt from 2015 IRC, Table R806.5 Insulation for Condensation Control

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Minimum rigid Board on Air-Impermeable Insulation R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2A, 2B, 3A, 3B, 3C</td>
<td>R-5</td>
</tr>
</tbody>
</table>

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 unvented attic assemblies that are considered part of the building thermal envelope.

2015 IECC/IRC, Section R402.1.3/N1102.1.3 or 2012 IECC/IRC, Section R402.1.2/N1102.1.2, 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 and Fenestration Requirements by Component Tables

2015 IECC/IRC, Table R402.1.2/N1101.1.2 or 2012 IECC/IRC, Table R402.1.1/N1102.1.1 (R-values are the same for both versions of IECC/IRC.)

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Ceiling R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
</tr>
<tr>
<td>2, 3</td>
<td>38</td>
</tr>
</tbody>
</table>

This means if air-impermeable insulation is installed in direct contact with the underside of the structural roof sheathing, a minimum of R-5 rigid foam board is required, and the sum of air-permeable insulation directly below the air-impermeable insulation must meet a minimum R-value of R-25 in climate zone 1 and R-33 in climate zones 2 and 3.

2015 IECC/IRC, Section R402.1.4/N1102.1.4 or 2012 IECC/IRC Section R402.1.3/N1102.1.3, U-Factor Alternative. An assembly with a U-factor equal to or less than that specified in tables should be permitted as an alternative to the R-value in the Insulation and Fenestration Requirements by Component Tables of the IECC/IRC.

Excerpt from the Equivalent U-Factor Tables

2015 IECC/IRC, Table R402.1.4/N1102.1.4 or 2012 IECC/IRC, Table R402.1.3/N1102.1.3. (U-factors are the same for both versions of the codes.)

<table>
<thead>
<tr>
<th>Climate Zone</th>
<th>Ceiling U-Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.035</td>
</tr>
<tr>
<td>2, 3</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Air Sealing/Air Leakage Control

2015 IECC/IRC, Section 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 [4] 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 unvented attics.

Air Barrier and Insulation Installation Table R402.4.1.1/N1102.4.1.1

- Continuous air barrier[5] – Confirm that construction documents specify a continuous air barrier for the building components associated with the insulation. Air-permeable insulation should not be used as a sealing material.

2015 IECC/IRC, Section R501.1.1/N1107.1.1, Alterations - General. Alterations to an existing building or portion thereof should comply with Section R502/N1108, R503/N1109 or R504/N1110. Unaltered portions of the existing building are not required to comply.
Section R503.1/N1109.1, General. Alterations to any building or structure should comply with the requirements of the code for new construction. Alterations should be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the alteration. Alterations should not create an unsafe or hazardous condition or overload existing building systems. Alterations should be such that the existing building or structure uses no more energy than the existing building or structure prior to the alteration.

Section R503.2/N1103.2, Change in space conditioning. Any non-conditioned or low-energy space that is altered to become conditioned space should be required to be in full compliance with this code. (This means not only the altered assembly is brought into compliance but the entire space or building also would need to be brought into compliance.)

Section R503.1.1/N1109.1.1, Building Envelope. Building envelope assemblies that are part of the alteration must comply with Sections R402.1.2/N1102.1.2 (Insulation and Fenestration Table) or R402.1.4/N1102.1.4 (U-Factor Alternative), and Sections R402.2.1/N1102.2.1 through R402.2.12/N1102.2.12, R402.3.1/N1102.3.1, R402.3.2/N1102.3.2, R402.4.3/N1102.4.3 and R402.4.4/N1102.4.4.

Exception: The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:

- Existing ceiling cavities exposed during construction, provided that the cavities are filled with insulation
- Construction where the existing roof cavity is not exposed
- Roof recover
- Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing should be insulated either above or below the sheathing.

[3] The term “building thermal envelope” is 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.

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

[5] The term “continuous air barrier” is defined as a combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

Field Inspection:

This section provides details for inspecting to the specific provisions for construction of unvented attics or enclosed unvented rafter assemblies, roof insulation, ventilation, and moisture controls where one or more specific types of inspection called for by the IECC or IRC may be necessary to confirm compliance. Framing and rough-in would be the typical type of inspection performed. (Bullet items underscored and highlighted in red are based on the new provisions for the 2018 IRC.)

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 footings and the foundation, framing and rough-in work, plumbing rough-in, mechanical rough-in, and final inspection.

Per the 2015 IRC, Section R109 Inspections, for onsite construction, from time to time 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 the foundation, plumbing, mechanical, gas and electrical, floodplain, frame and masonry, and the final inspection. Any additional inspections are at the discretion of the building official.

Inspections should provide verification with the following items if specified and approved on the construction documents and per manufacturer specifications and installation:

- Verify that joints, seams, holes, and penetrations are caulked, gasketed, weather-stripped, or otherwise sealed (assemblies part of the building thermal envelope).
- Ensure that the appearance of the insulation, as appropriate, in the field matches what is on the approved construction documents.
- If the R-value or U-factor approach for compliance was used in the documentation, ensure that the insulation installed meets the minimum R-value(s) specified for the assembly per climate zone based upon the approved construction documents.
• Confirm that the continuous air barrier is properly installed.
• Where preformed insulation board is used as the air-impermeable insulation layer, confirm that it is sealed at the perimeter of each individual sheet interior surface to form a continuous layer.
• Confirm that the vapor diffusion port(s) are installed per the approved construction documents.
• Confirm that the moisture barrier material used for the vapor diffusion port(s) is the same material specified on the approved construction documents.
• Confirm that the air supplied to the conditioned attic meets the approved construction documents.

Technical Validation(s):

This section provides additional related information and references to materials that are applicable to the provision.

• **2015 IECC—International Energy Conservation Code**
  Author(s): ICC  
  Organization(s): ICC  
  Publication Date: 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.

• **2015 IRC—International Residential Code for One- and Two-Family Dwellings**
  Author(s): ICC  
  Organization(s): ICC  
  Publication Date: 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.

• **Understanding Attic Ventilation**
  Author(s): J. Lstiburek  
  Organization(s): Building Science Corporation (BSC)  
  Publication Date: October 2006  
  This report provides guidance about whether to construct a vented or unvented attic based on hygro-thermal zone.


Related BASC Guides:


• Ceilings, [https://basc.pnnl.gov/resource-guides/ceilings#quicktabs-guides=6](https://basc.pnnl.gov/resource-guides/ceilings#quicktabs-guides=6)


More Info.

Access to some references 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.

Case Studies
None Available

References and Resources*

1. **Foam Shrinks, and Other Lessons**
   - Author(s): Lstiburek
   - Organization(s): Building Science Corporation
   - Publication Date: March, 2012
   - *Journal article describing lessons learned from updating a 16-year-old deep-energy retrofit.*

2. **High-R Roofs Case Study Analysis**
   - Author(s): Straube, Grin
   - Organization(s): Building Science Corporation
   - Publication Date: March, 2009
   - *Report that considers a number of promising wall systems that can meet the requirement for better thermal control.*

3. **National Grid Deep Energy Retrofit Pilot**
   - Author(s): Neuhauser
   - Organization(s): Building Science Corporation
   - Publication Date: March, 2012
   - *Report about a test home project evaluating strategies to elevate the performance of existing homes to a level commensurate with best-in-class implementation of high performance new construction homes.*

4. **Proven Performance of Seven Cold Climate Deep Retrofit Homes**
   - Author(s): Osser, Neuhauser, Ueno
   - Organization(s): Building Science Corporation, National Renewable Energy Laboratory
   - Publication Date: June, 2012
   - *Report about seven pilot homes and development of guidelines for deep energy retrofits in cold climates.*

*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.

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