

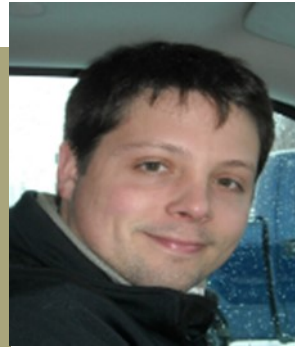
A close-up photograph of a person's hand pointing at architectural blueprints on a desk. Another hand is holding a pen over the plans. A laptop is visible in the background, and the scene is lit with warm, golden light. A semi-transparent green box is overlaid on the left side of the image, containing the title and subtitle text.

# The Process of Achieving an Airtight Homes

Where do we start?

## Emmett Leffel

- ❖ Certified AHFC Rater
- ❖ ABAA Certified Air Barrier Auditor
- ❖ ITC Level II Thermographer
- ❖ Air Barrier Testing Professional
- ❖ Combustion Safety Specialist
- ❖ SOA Mechanical Administrator
- ❖ SOA Plumbing License.
- ❖ UA Journeyman Pipefitter/Plumber



# Speaker



Emmett has traveled across the State of Alaska performing building diagnostic on everything from Natatoriums in South East Alaska to Groceries Stores in the Aleutians and energy audits on residential and commercial audits across Alaska for the last 10 years. Before becoming an Energy Professional, Emmett worked in the heating and plumbing industry in the interior of Alaska.

[www.alaskathermalimaging.com](http://www.alaskathermalimaging.com)



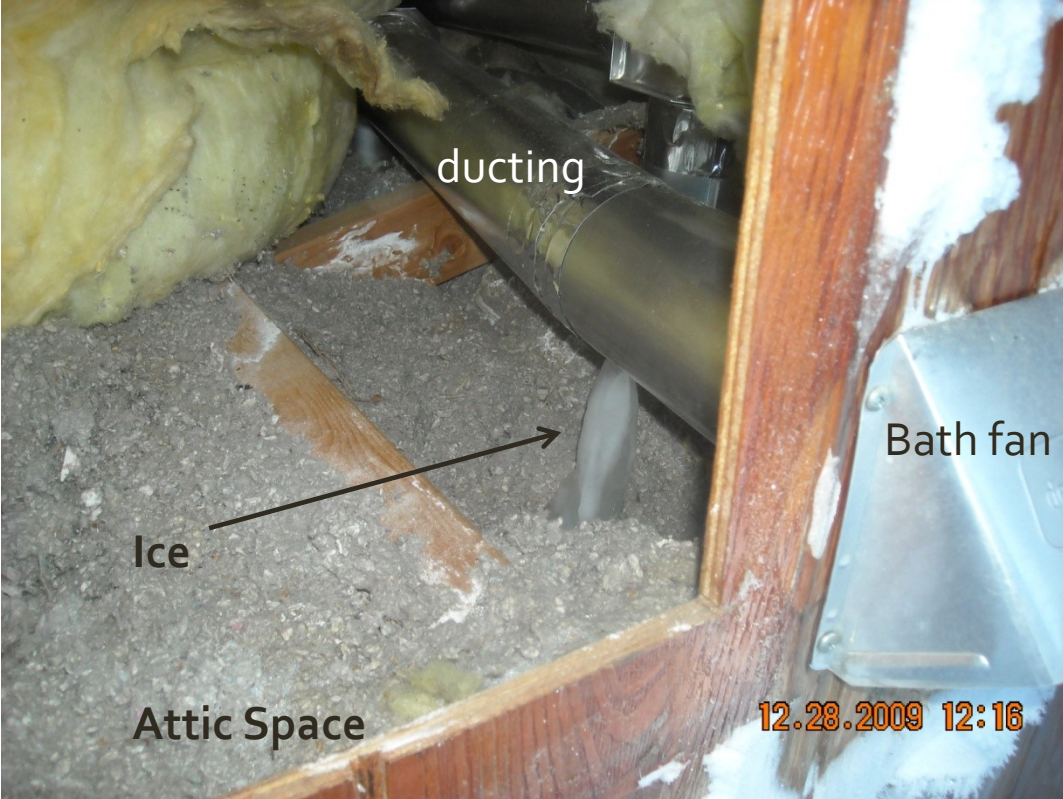
ALASKA CENTER  
for Appropriate Technology



COLD CLIMATE HOUSING RESEARCH CENTER  
CCHRC

# Visible signs of exfiltration and building degradation





Moisture control and air barrier design are also some of the most important durability measures necessary for an efficient home.

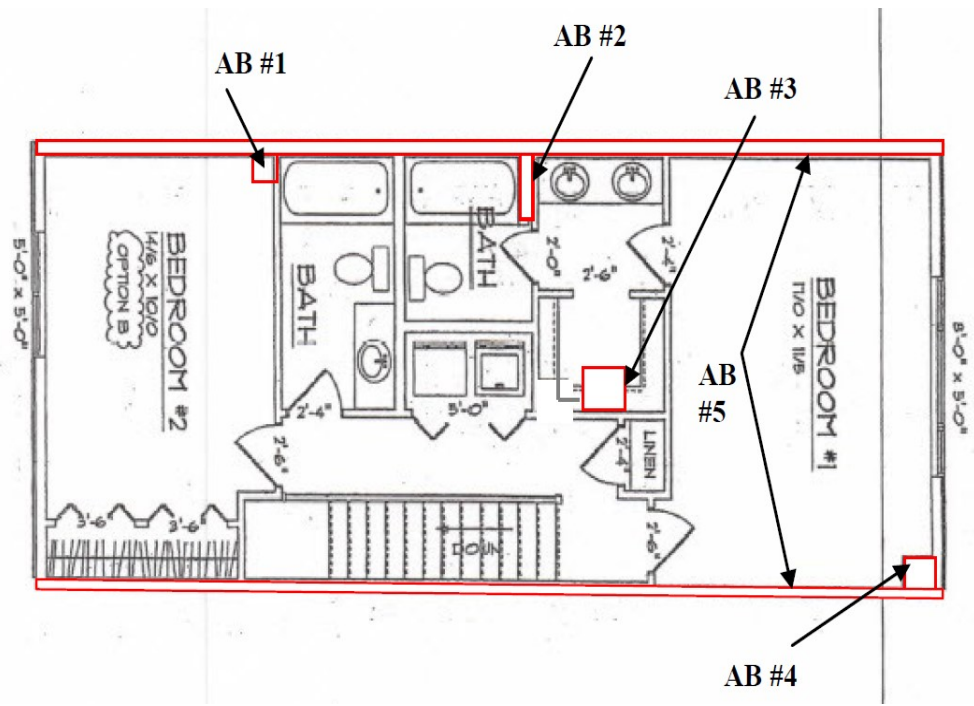




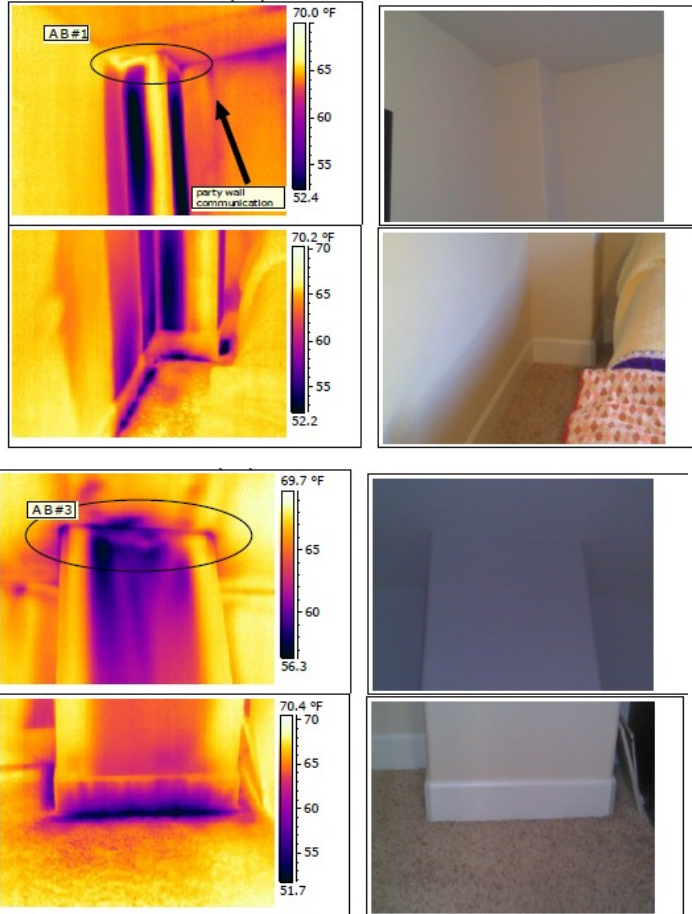
Ice damming is an obvious condition indicating air leakage and heat loss. It can amount to tens of thousand of dollars in damage: structural failure, water intrusion, damaged insulation, and even mold.



3RD FLOOR LAYOUT  
SCALE 3/8" = 1'-0"



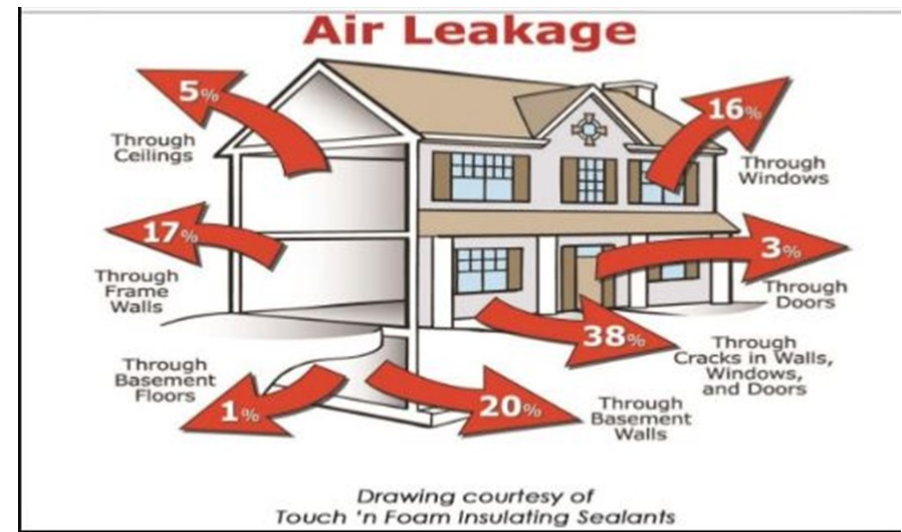
A.B. = Attic Bypass



Attic Bypasses are a principal air leakage pathway that are required to be sealed.

# Air Barriers in Codes

- **2012 International Energy Conservation Code cont'd**
- R402.4 Air leakage (Mandatory) – requirement for air leakage of the thermal envelope shall comply with the noted sections of this code.
- R402.4.1 Building thermal envelope – requirement for sealing between dissimilar materials
- R402.4.1.1 Installation - requirements of the thermal envelope (air barrier) shall be installed as per manufacturer's instructions.
- Table R402.4.1.1 Air Barrier & Insulation Installation
- R402.4.1.2. Testing - requirements for building envelope air leakage testing



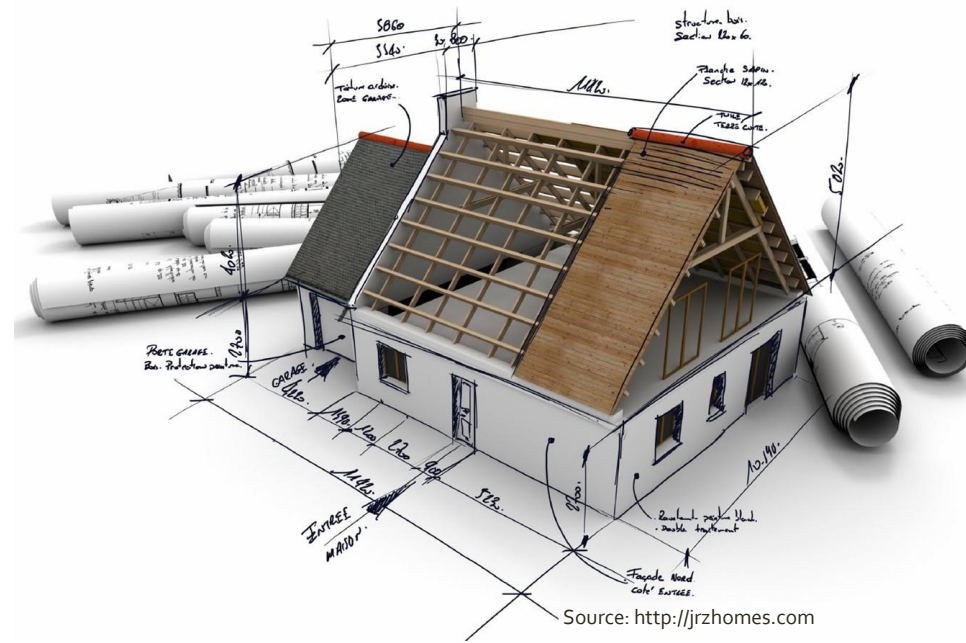
# IECC Airtight

## Air Barrier System Commissioning

1. The building thermal envelope shall be constructed to limit air leakage in accordance with IECC requirements.
  - Inspection by ICC Inspectors (AK only)
  - Air leakage testing by Energy Auditors
2. Components of the air barrier and other required air sealing shall be installed in accordance with the manufacturer's instructions and the criteria indicated in IECC Table R402.4.1.1.
3. Whole Building Air Leakage  $\leq 4 \text{ ach}_{50}$  (BEES Amended)

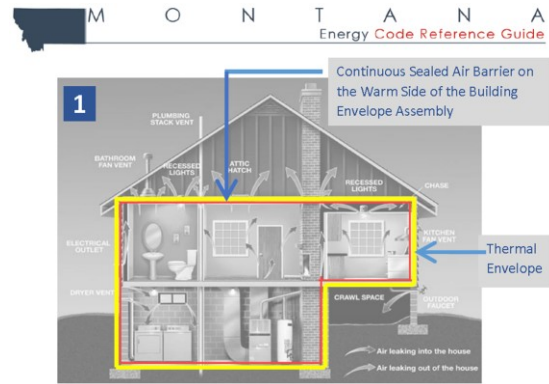


# What is Airtight



- IECC > 3 air changes per hour @50 Pascals Climate Zone 8
- AK BEES > 4ach@50 (w/ Mandatory Measures)
- Energy Star – 3ach50 Climate Zone 8 (w/ Inspection Requirements)
- DOE Zero Energy Ready Home – 2ach50 CZ-7  
(w/ Inspection Requirements) – 1.5ach50 CZ-8
- Passive House – 0.6ach50 (w/ Inspection Requirements)

# Air Sealing Must Be Systematic.



- Designed



- Inspected



- Tested

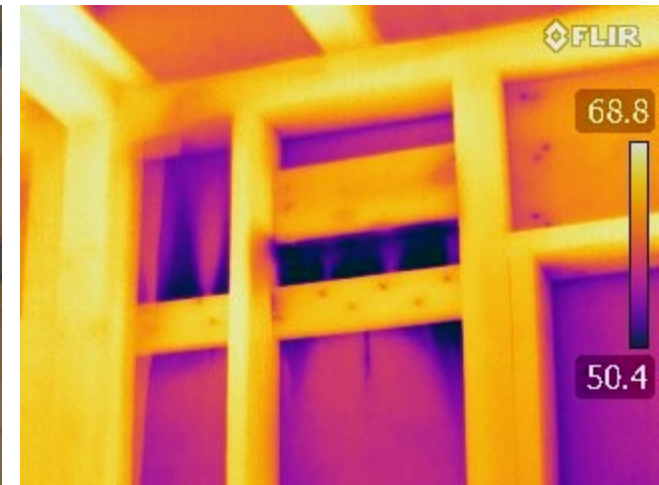
**Pre-Air Barrier  
Testing:**  
Inspection & diagnostics



**Final Air Leakage  
Testing:**  
Compliance Verification

Air Barrier Testing can be broke into  
Two Categories

# Higher Levels of Efficiency & Performance Require Higher Levels of Testing.



# ABAA-Air barrier association of America

incorporated in the State of Massachusetts in 2001

## Material Performance:

Air barrier materials must have an air permeance not to exceed 0.004 cfm/ft<sup>2</sup> @ 1.57 psf(75pa) when tested in accordance with ASTM E2178 (unmodified).

[https://archive.airbarrier.org/materials/index\\_e.php](https://archive.airbarrier.org/materials/index_e.php)

- Self-adhered Sheet Air Barriers
- Liquid Applied Membranes
- Medium Density Sprayed Polyurethane Foam (SPF)
- Mechanically Fastened Commercial Building Wraps
- Boardstock – Rigid Cellular Thermal Insulation Board

[https://www1.eere.energy.gov/buildings/publications/pdfs/building\\_america/building\\_materials\\_property\\_table.pdf](https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/building_materials_property_table.pdf)

## Assembly Performance:

Provide a continuous air barrier in the form of an assembly that has an air leakage not to exceed 0.04 cubic feet per minute per square foot under a pressure differential of 1.57 pounds per square foot (0.04 cfm/ft<sup>2</sup> @ 1.57 psf) when tested in accordance with ASTM E2357.

The assembly shall

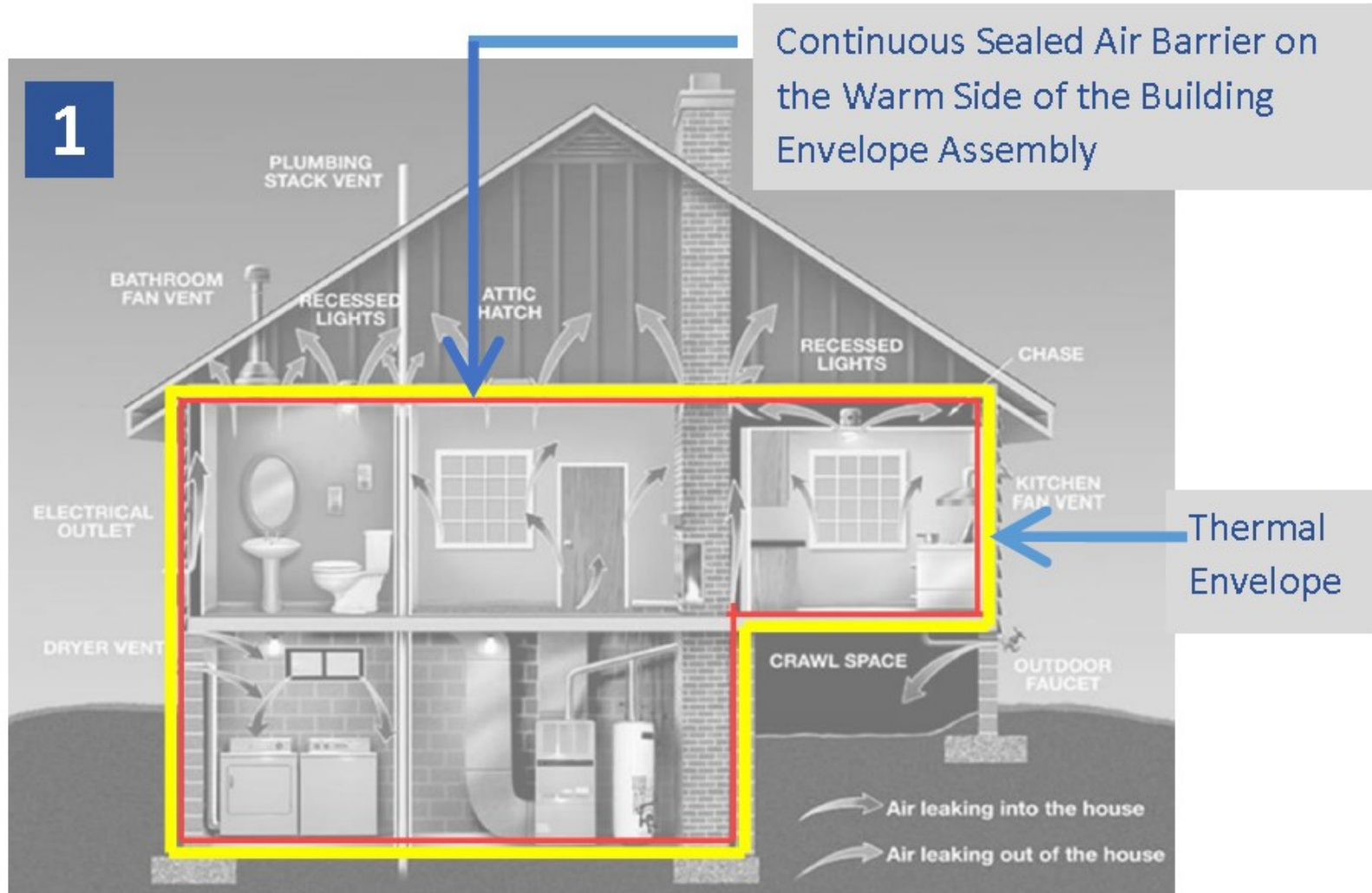
- accommodate movements of building materials by providing expansion and control joints as required.
- be capable of withstanding combined design wind, fan and stack pressures.
- Materials of the air barrier assembly shall not displace adjacent materials in the assembly under full load.
- allow for the relative movement of assemblies due to thermal and moisture variations, creep, and anticipated seismic movement.

# DETAILS - CONSTRUCTION - TESTING

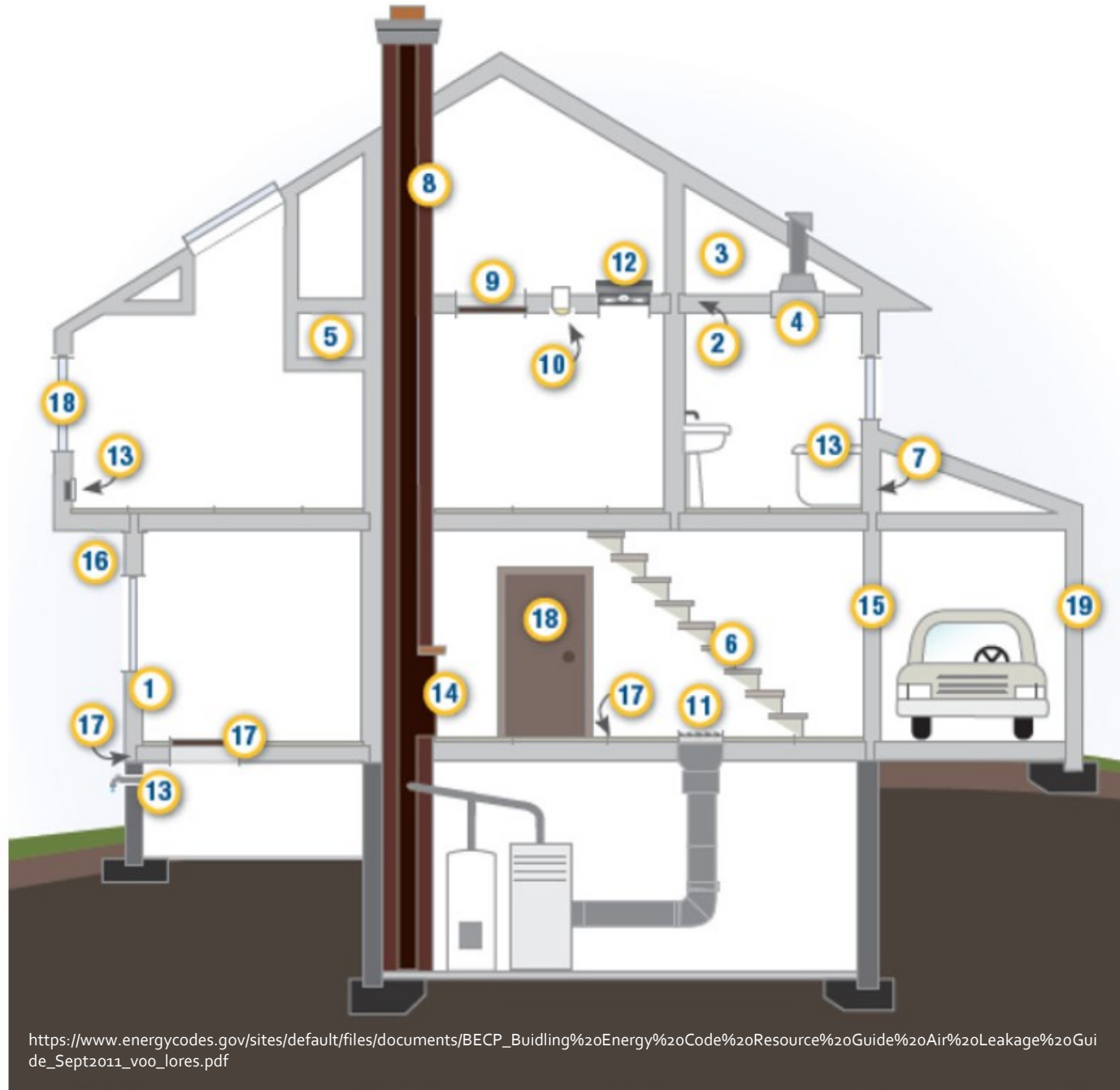




# TABLE R402.4.1.1 AIR BARRIER AND INSULATION INSTALLATION



## Air Sealing Trouble Spots



- 1 Air Barrier and Thermal Barrier Alignment
- 2 Attic Air Sealing
- 3 Attic Kneewalls
- 4 Shaft for Piping or Ducts
- 5 Dropped Ceiling/Soffit
- 6 Staircase Framing at Exterior Wall
- 7 Porch Roof
- 8 Flue or Chimney Shaft
- 9 Attic Access
- 10 Recessed Lighting
- 11 Ducts
- 12 Whole-House Fan
- 13 Exterior Wall Penetrations
- 14 Fireplace Wall
- 15 Garage/Living Space Walls
- 16 Cantilevered Floor
- 17 Rim Joists, Sill Plate, Foundation, Floor
- 18 Windows & Doors
- 19 Common Walls Between Attached Dwelling Units





# ENERGY STAR Qualified Homes, Version 3 (Rev. 06) Thermal Enclosure System Rater Checklist

Home Address: _____		City: _____		State: _____	
		<b>Must Correct</b>	<b>Builder Verified <sup>1</sup></b>	<b>Rater Verified</b>	<b>N/A</b>
<b>3. Fully-Aligned Air Barriers <sup>6</sup></b>					
At each insulated location noted below, a complete air barrier shall be provided that is fully aligned with the insulation as follows:					
<ul style="list-style-type: none"> <li>• At interior or exterior surface of ceilings in Climate Zones 1-3; at interior surface of ceilings in Climate Zones 4-8. Also, include barrier at interior edge of attic eave in all climate zones using a wind baffle that extends to the full height of the insulation. Include a baffle in every bay or a tabbed baffle in each bay with a soffit vent that will also prevent wind washing of insulation in adjacent bays</li> <li>• At exterior surface of walls in all climate zones; and also at interior surface of walls for Climate Zones 4-8<sup>7</sup></li> <li>• At interior surface of floors in all climate zones, including supports to ensure permanent contact and blocking at exposed edge<sup>8,9</sup></li> </ul>					
<b>3.1 Walls <sup>10</sup></b>					
3.1.1	Walls behind showers and tubs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.2	Walls behind fireplaces	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.3	Attic knee walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.4	Skylight shaft walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.5	Wall adjoining porch roof	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.6	Staircase walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.7	Double walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.8	Garage rim / band joist adjoining conditioned space	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.1.9	All other exterior walls	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3.2 Floors</b>					
3.2.1	Floor above garage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2.2	Cantilevered floor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.2.3	Floor above unconditioned basement or unconditioned crawlspace	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>3.3 Ceilings <sup>10</sup></b>					
3.3.1	Dropped ceiling / soffit below unconditioned attic	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3.3.2	All other ceilings	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

# Energy Star Thermal Enclosure System Rater Checklist

- Fenestrations
- Insulation
- Aligned Air Barrier
- Thermal Bridging

<https://www.youtube.com/watch?v=hb5LmY3Rj2o>



## SECTION 3. FULLY ALLIGNED AIR BARRIERS <sup>6</sup>

At each insulated location noted below, a complete air barrier shall be provided that is fully aligned with the insulation as follows:

- At interior or exterior surface of ceilings in Climate Zones 1-3; at interior surface of ceilings in Climate Zones 4-8. Also, include barrier at interior edge of attic eave in all climate zones using a wind baffle that extends to the full height of the insulation. Include a baffle in every bay or a tabbed baffle in each bay with a soffit vent that will also prevent wind washing of insulation in adjacent bays
- At exterior surface of walls in all climate zones; and also at interior surface of walls for Climate Zones 4-8 <sup>7</sup>
- At interior surface of floors in all climate zones, including supports to ensure permanent contact and blocking at exposed edge <sup>8,9</sup>



## **SECTION 3. FULLY ALLIGNED AIR BARRIERS <sup>6</sup>**

### **3.1 Walls<sup>10</sup>**

3.1.1 Walls behind showers and tubs

3.1.2 Walls behind fireplaces

3.1.3 Attic knee walls

3.1.4 Skylight shaft walls

3.1.5 Wall adjoining porch roof

3.1.6 Staircase walls

3.1.7 Double walls

3.1.8 Garage rim / band joist adjoining conditioned space

3.1.9 All other exterior walls



## **SECTION 3. FULLY ALLIGNED AIR BARRIERS <sup>6</sup>**

### **3.2 Floors**

3.2.1 Floor above garage

3.2.2 Cantilevered floor

3.2.3 Floor above unconditioned basement or unconditioned crawlspace

### **3.3 Ceilings<sup>10</sup>**

3.3.1 Dropped ceiling/soffit below unconditioned attic

3.3.2 All other ceilings

**DETAIL 3.1.1** <sup>6,7,10</sup>**Walls behind showers and tubs**

- A. Install insulation without misalignments, compressions, gaps, or voids in all exterior wall cavities behind all tubs and showers.
- B. Back with a rigid air barrier or other supporting material to prevent insulation from sagging and create a continuous thermal barrier.\*
- C. Seal all seams, gaps, and holes of the air barrier with caulk or foam before tub/shower installation.

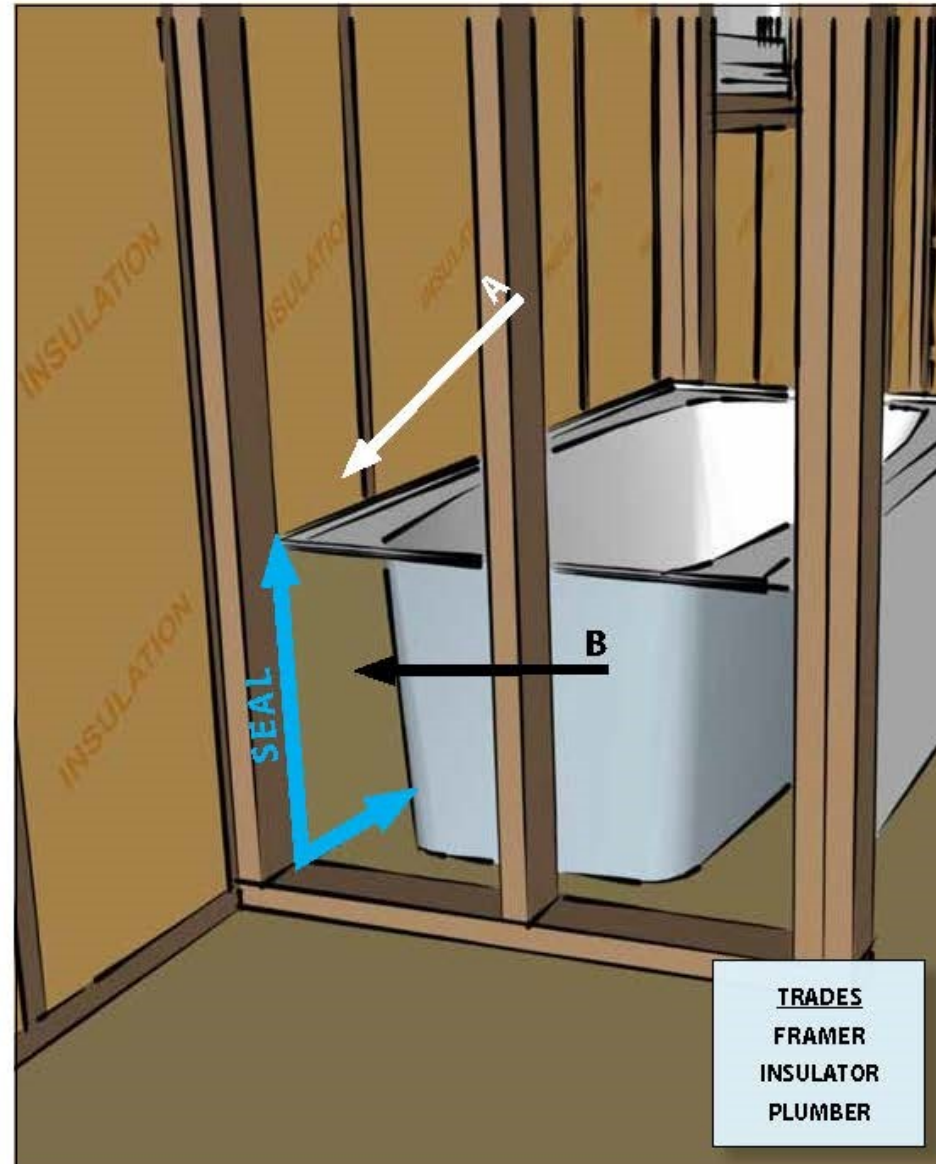
\* EPA recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



# 3.1.1

## Walls behind showers and tubs



No air barrier installed prior to tub installation.

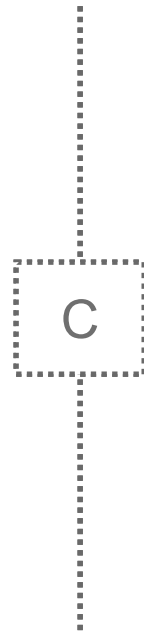


Air barrier installed behind the tub.

# 3.1.1 Walls behind showers and tubs



Air barrier not sealed.



Air barrier sealed.

**DETAIL 3.1.2<sup>6,7,10</sup>****Walls behind fireplaces**

- A. Install insulation without misalignments, compressions, gaps, or voids in all exterior wall cavities behind all fireplaces.
- B. Back with a fire-proof rigid air barrier or other supporting material to create a continuous thermal barrier and prevent a fire hazard.\*
- C. Seal all seams, gaps, and holes of the air barrier with fire-rated caulk or foam before fireplace installation.

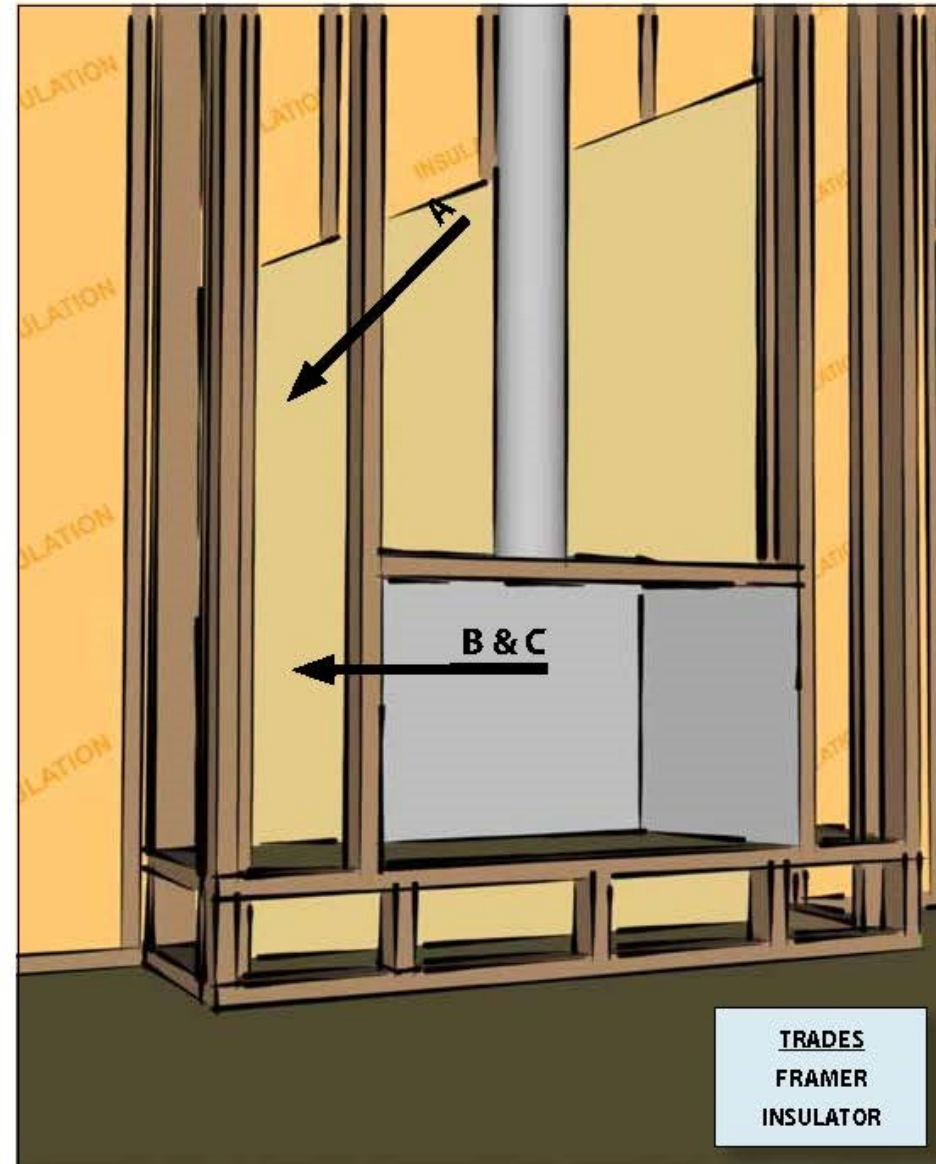
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5$ " or 1.5", respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1$ " diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.





## 3.1.2 Walls behind fireplaces



No rigid air barrier is installed behind fireplace.



Rigid air barrier is installed behind fireplace.

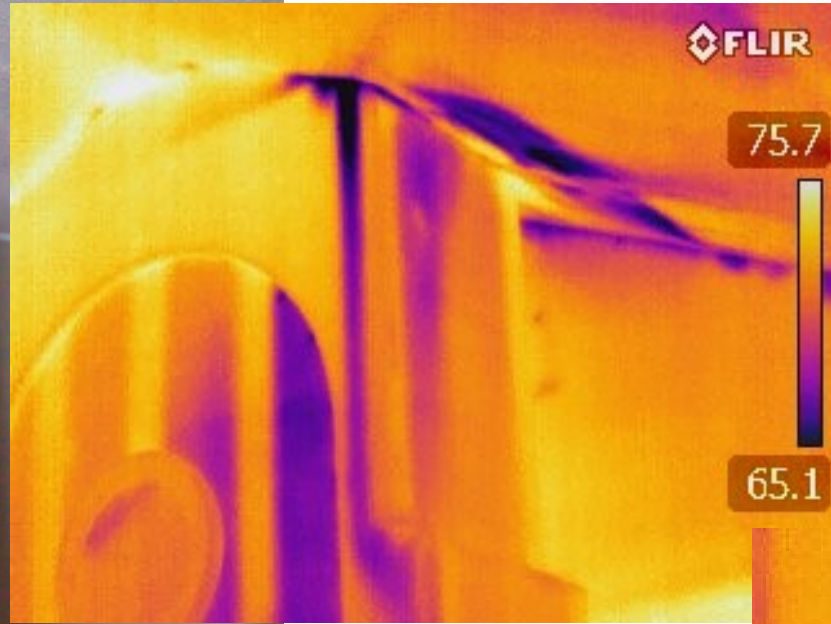
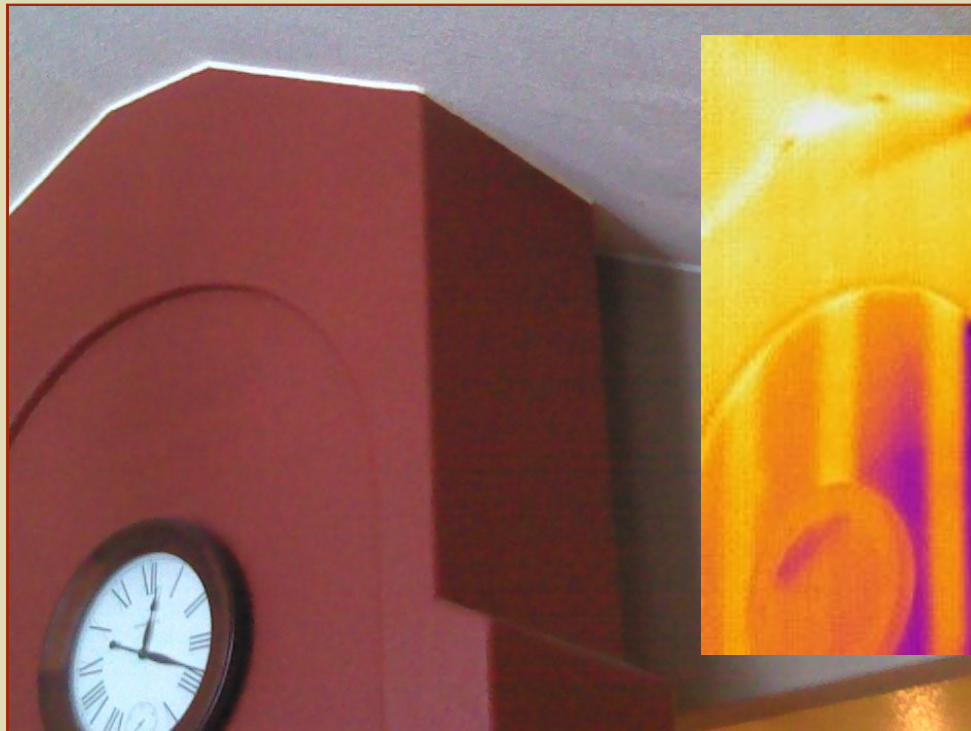
## 3.1.2 Walls behind fireplaces



Vent sleeve not completely sealed.



Vent and air barrier sealed.



**DETAIL 3.1.3** <sup>6,7,10</sup>**Attic knee walls**

- A. Install a top and bottom plate or blocking at the top and bottom of all knee wall cavities.
- B. Back attic knee walls with a rigid air barrier or other supporting material to prevent insulation from sagging and create a continuous thermal barrier.\*
- C. Seal all seams, gaps, and holes of the air barrier with caulk or foam.
- D. Install insulation without misalignments, compressions, gaps, or voids in all knee wall cavities.

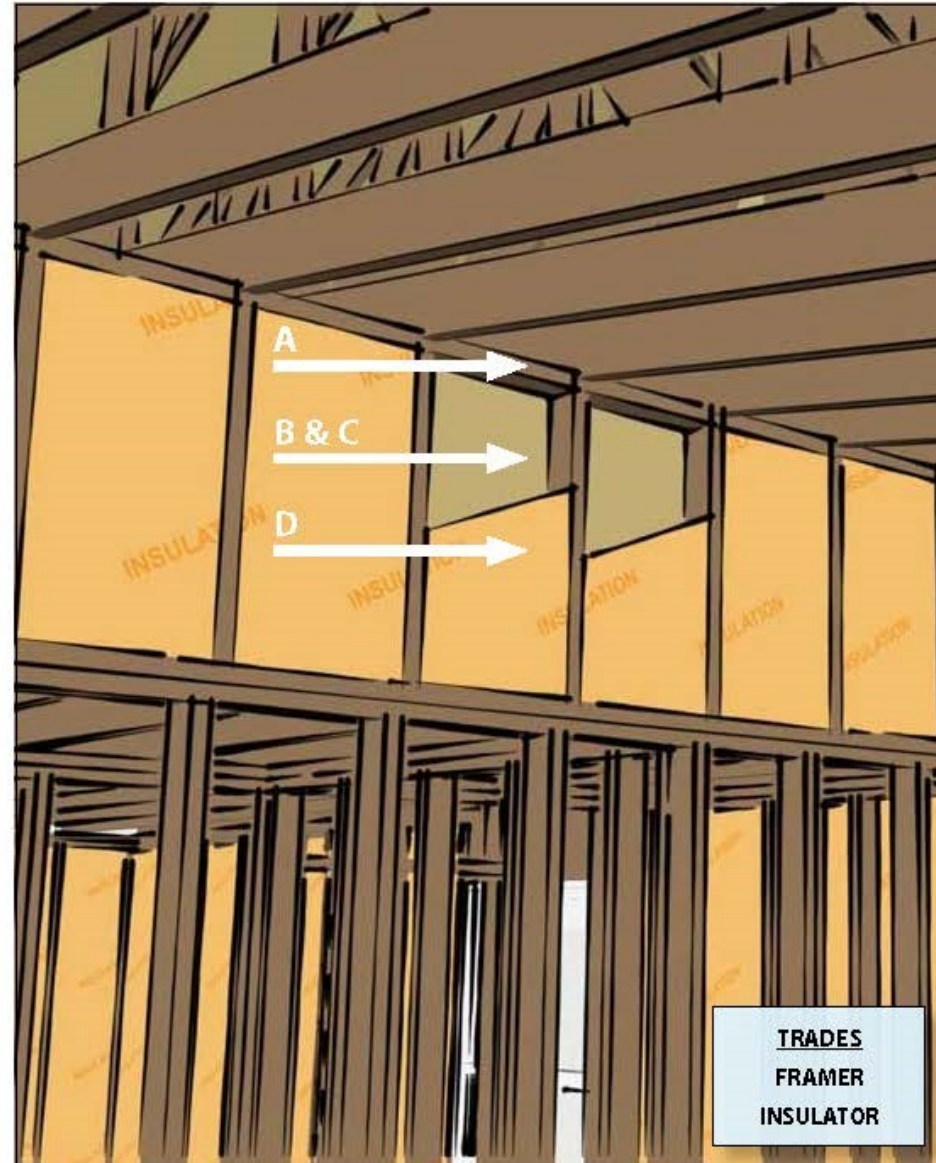
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



**TRADES**  
**FRAMER**  
**INSULATOR**

### 3.1.3 Attic knee walls



No rigid backing on knee wall.



Rigid backing installed prior to insulation.

# 3.1.3 Attic knee walls



Backing not air sealed prior to insulation.



Backing air sealed prior to insulation.

**DETAIL 3.1.4** <sup>6,7,10</sup>**Skylight shaft walls**

- A. If non-rigid insulation is used, install a rigid air barrier to prevent insulation from sagging and create a continuous thermal barrier.\*
- B. Seal all seams, gaps, and holes of the air barrier with caulk or foam.
- C. Install the insulation without any misalignments, compressions, gaps, or voids so that it acts as both the air barrier and thermal boundary. *Examples include foam board, spray foam or dense pack insulation.*

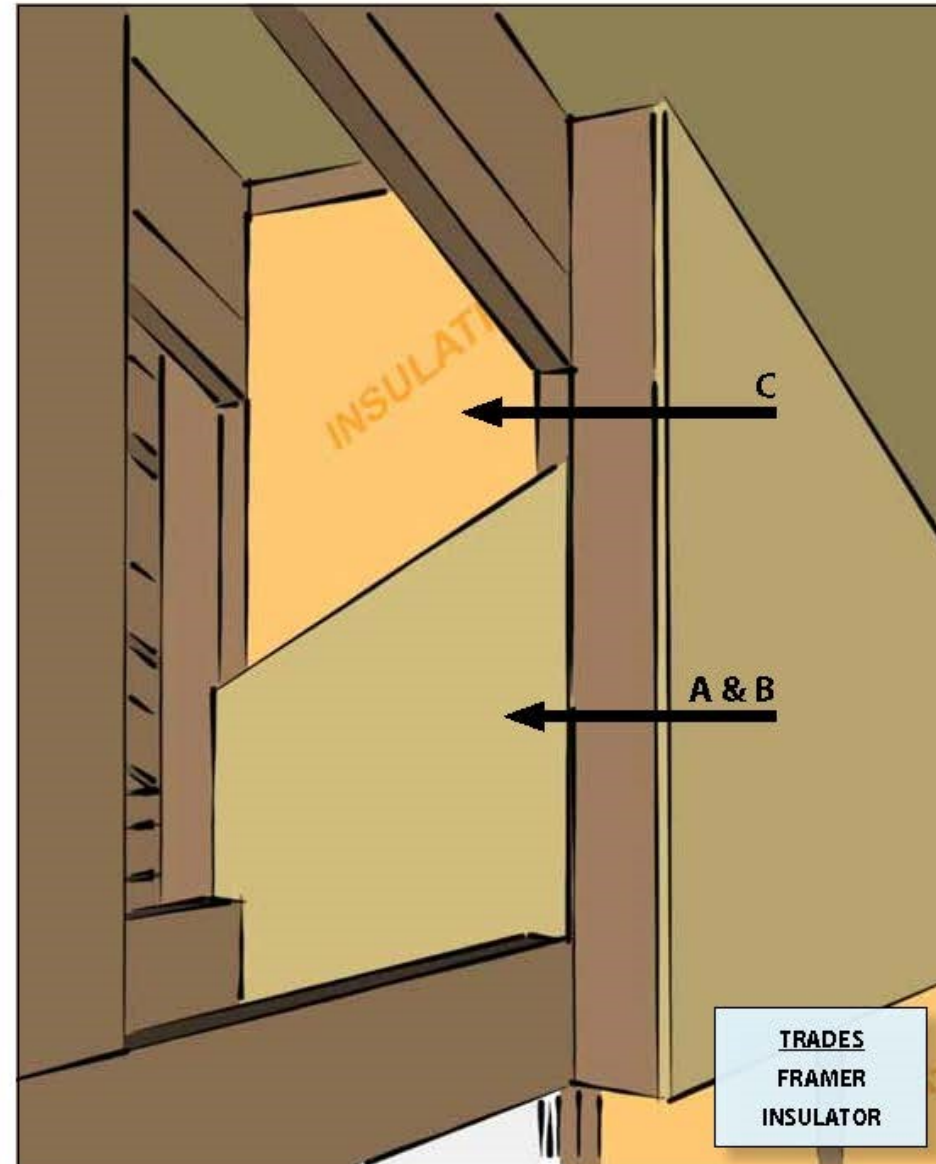
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



## 3.1.4 Skylight shaft walls



Rigid air barrier not installed to hold insulation in place.



Rigid air barrier is installed to hold insulation in place.



**DETAIL 3.1.5<sup>6,7,10</sup>****Wall adjoining porch roof**

- A. Install a rigid air barrier or other supporting material to separate the porch attic from the conditioned space.\*
- B. Seal all seams, gaps, and holes of the air barrier with caulk or foam before building wrap installation.

\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5$ " or 1.5", respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1$ " diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



## 3.1.5 Wall adjoining porch roof



No air barrier between porch attic and conditioned space.



Air barrier is installed prior to porch attic framing.

**DETAIL 3.1.6<sup>6,7,10</sup>****Staircase walls**

- A. Install insulation without misalignments, compressions, gaps, or voids in all exterior wall cavities underneath all staircases.
- B. Install a rigid air barrier to prevent insulation from sagging and create a continuous thermal barrier.\*
- C. Seal all seams, gaps, and holes of the air barrier with caulk or foam.

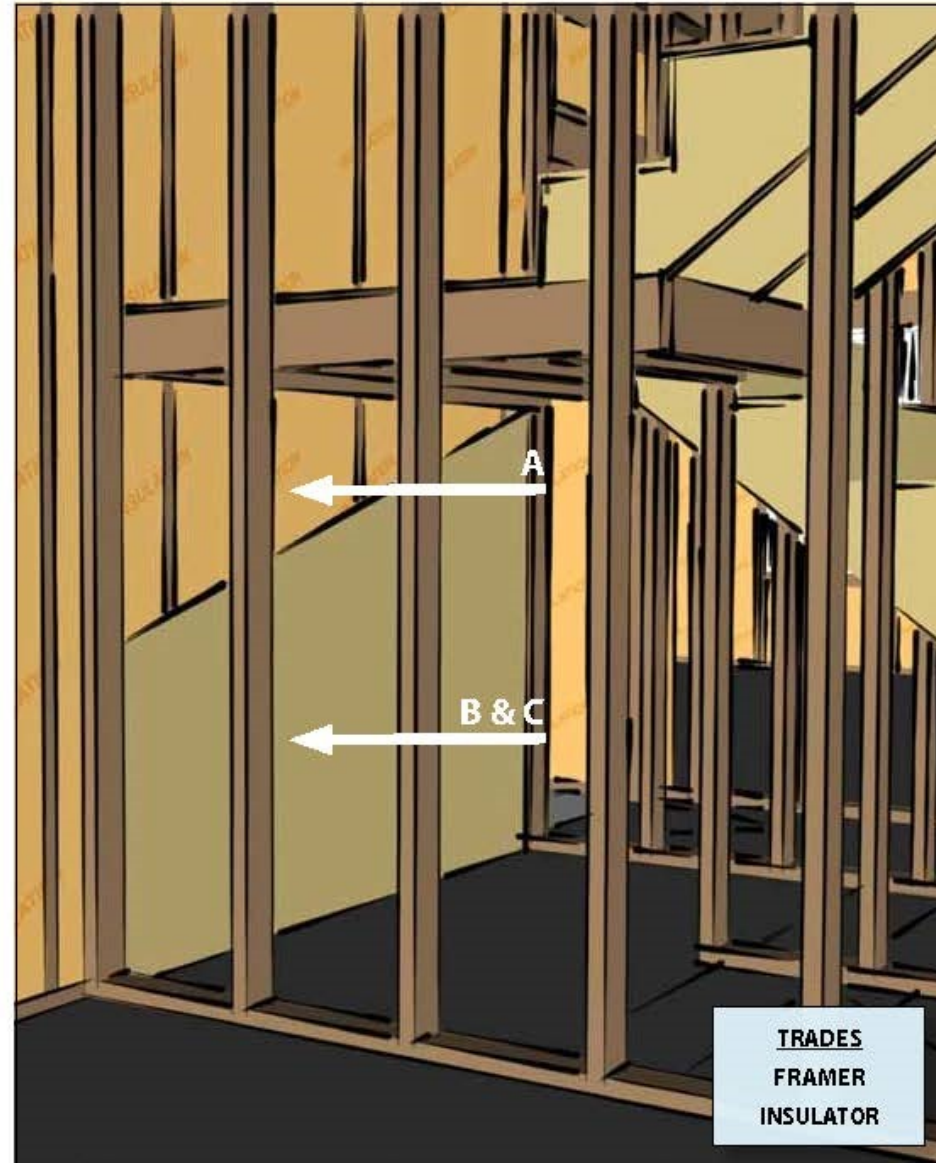
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



## 3.1.6 Staircase walls



No air barrier installed under staircase.



Air barrier installed under staircase.  
*Picture taken from house looking into attached garage.*

**DETAIL 3.1.8** <sup>6,7,10</sup>**Garage rim/band joist adjoining conditioned space**

- A. Install a continuous rigid air barrier or other supporting material to separate the garage from the conditioned space.\*
- B. Seal all seams, gaps, and holes of the air barrier with caulk or foam and complete before installing the insulation.
- C. Install insulation without misalignments, compressions, gaps, or voids in all band joist cavities.

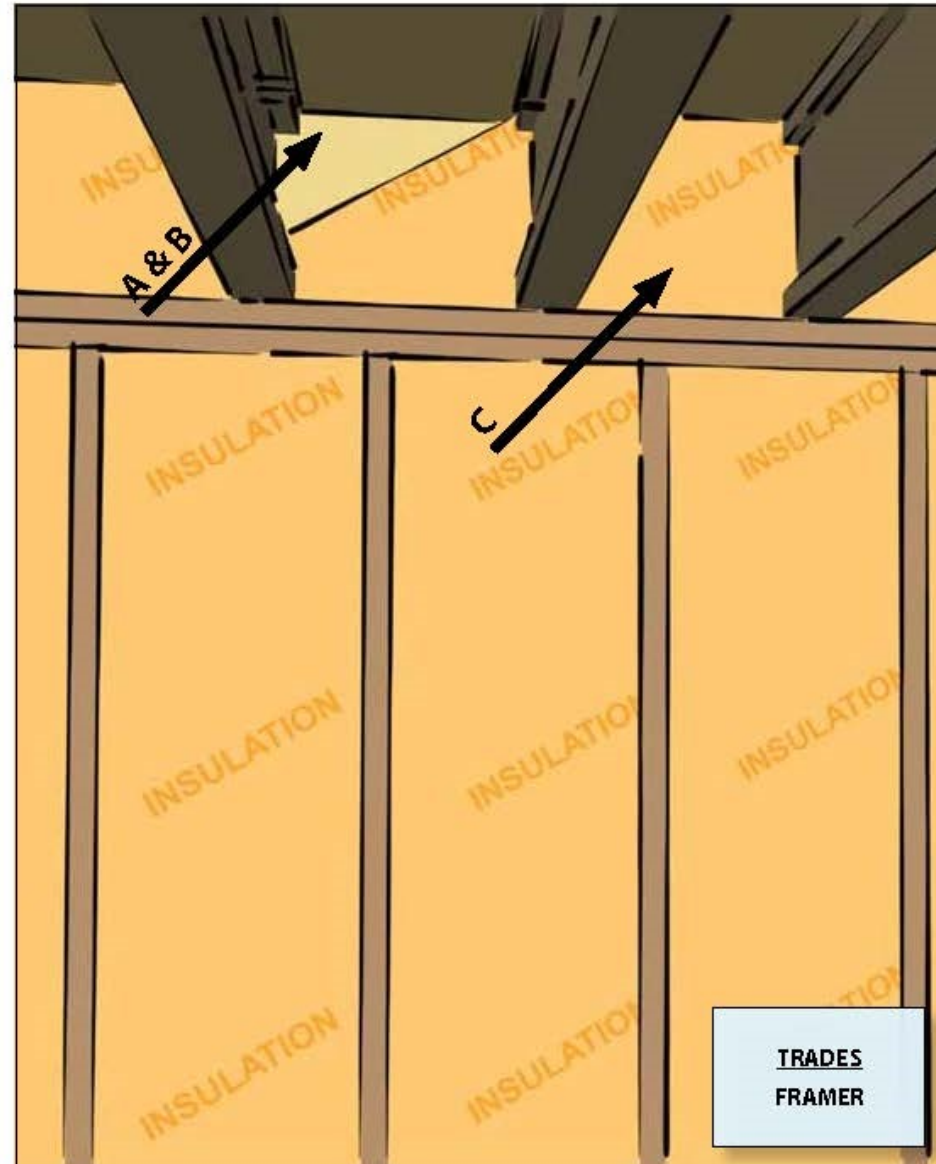
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

7. EPA highly recommends, but does not require, inclusion of an interior air barrier at band joists in Climate Zone 4 through 8.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



# 3.1.8

## Garage rim / band joist adjoining conditioned space



Gaps without insulation and not properly sealed.



Band is properly insulated and sealed.

FLIR

67.8

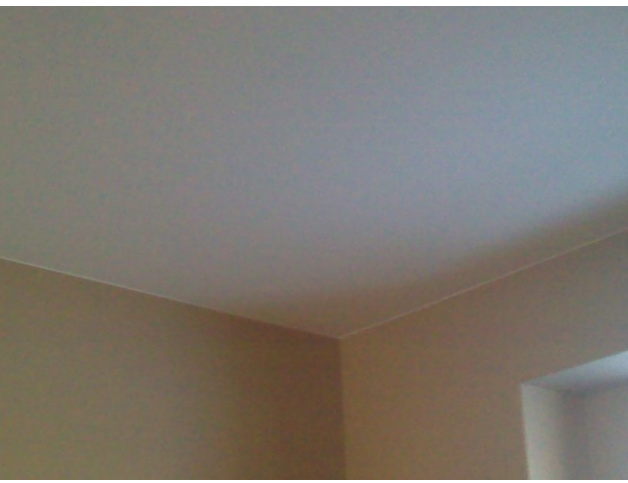
56.9

# 5

## Rim Joists

Rim joists shall be insulated and include the air barrier.

MONTANA  
Energy Code Reference Guide  
Based on the 2012 IECC as amended by Montana in 2014



**DETAIL 3.2.2<sup>6,8,9</sup>****Cantilevered floor**

- A. Install a rigid air barrier or other supporting blocking to separate the cantilever from the conditioned space.\*
- B. Seal all seams, gaps, and holes of the air barrier with caulk or foam.
- C. Install insulation without misalignments, compressions, gaps, or voids and align it with the sub-floor, the rigid air barrier (A), and the exterior face of the cavity.
- D. Once insulated, enclose the cavity with a rigid air barrier material.

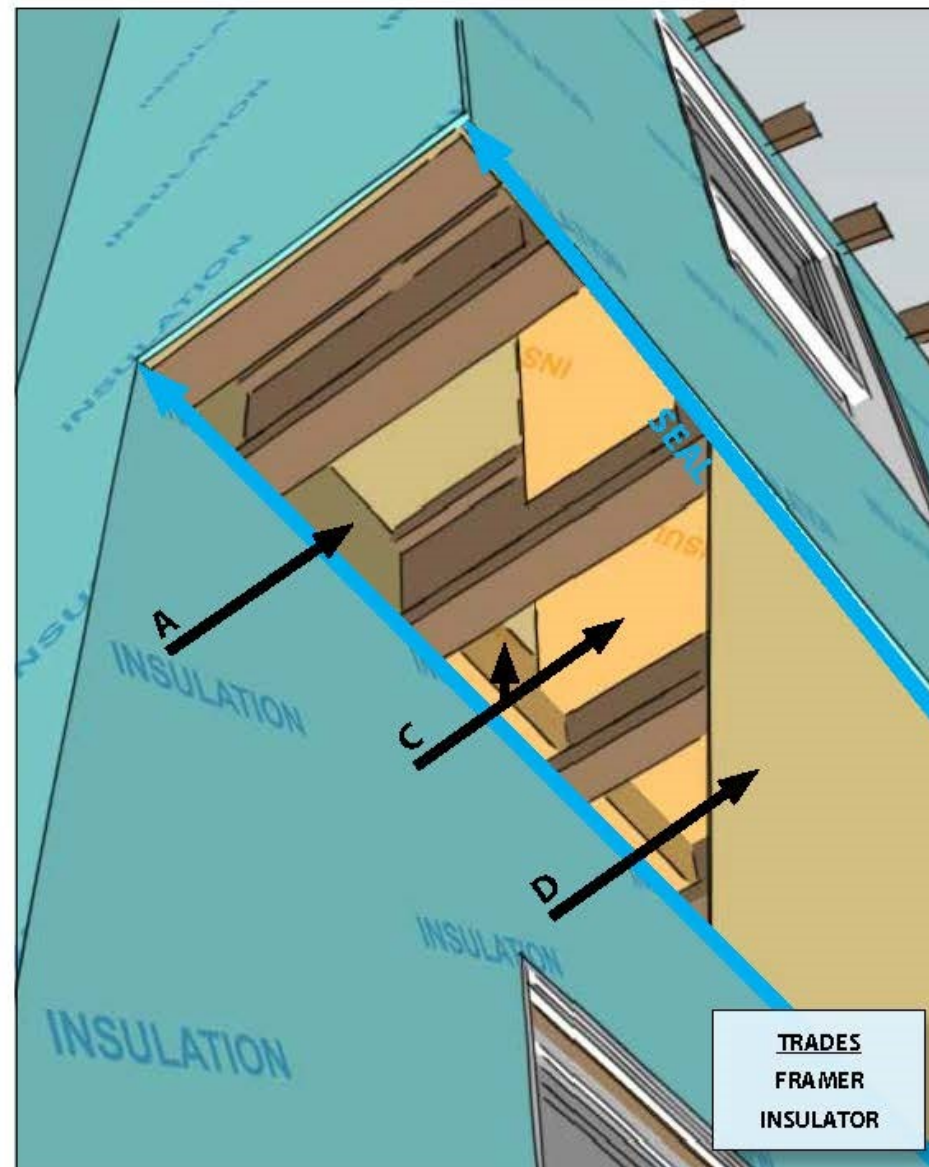
\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

8. Examples of supports necessary for permanent contact include staves for batt insulation or netting for blown-in insulation. Batts that completely fill a cavity enclosed on all six sides may be used to meet this requirement without the need for supports, even though some compression will occur due to the excess insulation, as long as the compressed value meets or exceeds the required insulation level. Specifically, the following batts may be used in six-sided floor cavities: R-19 batts in 2x6 cavities, R-30 batts in 2x8 cavities, R-38 batts in 2x10 cavities, and R-49 batts in 2x12 cavities. For example, in a home that requires R-19 floor insulation, an R-30 batt may be used in a six-sided 2x8 floor cavity.

9. Fully-aligned air barriers may be installed at the exterior surface of the floor cavity in all Climate Zones if the insulation is installed in contact with this exterior air barrier and the perimeter rim and band joists of the floor cavity are also sealed and insulated to comply with the fully-aligned air barrier requirements for walls.





## 3.2.2

## Cantilevered floor



No air barrier is present between cantilever and conditioned space.



GOOD PIC OF PROPERLY BLOCKED CANTILEVER

**DETAIL 3.3.1 <sup>6,10</sup>****Dropped ceiling/soffit below unconditioned attic**

- A. Install a continuous rigid air barrier or other supporting material to cap the dropped ceiling and soffits.\*
- B. Seal all seams, gaps, and holes of the air barrier with caulk or foam before installation of attic insulation.

\* EPA highly recommends using a rigid air barrier, but it is not a requirement.

**FOOTNOTES**

6. For purposes of this checklist, an air barrier is defined as any durable solid material that blocks air flow between conditioned space and unconditioned space, including necessary sealing to block excessive air flow at edges and seams and adequate support to resist positive and negative pressures without displacement or damage. EPA recommends, but does not require, rigid air barriers. Open-cell or closed-cell foam shall have a finished thickness  $\geq 5.5"$  or  $1.5"$ , respectively, to qualify as an air barrier unless the manufacturer indicates otherwise. If flexible air barriers such as house wrap are used, they shall be fully sealed at all seams and edges and supported using fasteners with caps or heads  $\geq 1"$  diameter unless otherwise indicated by the manufacturer. Flexible air barriers shall not be made of kraft paper, paper-based products, or other materials that are easily torn. If polyethylene is used, its thickness shall be  $\geq 6$  mil.

10. All insulated vertical surfaces are considered walls (e.g., exterior walls, knee walls) and must meet the air barrier requirements for walls. All insulated ceiling surfaces, regardless of slope (e.g., cathedral ceilings, tray ceilings, conditioned attic roof decks, flat ceilings, sloped ceilings), must meet the requirements for ceilings.



**TRADES**  
FRAMER  
INSULATOR

# 3.3.1

## Dropped ceiling/soffit below unconditioned attic



No air barrier is present between the dropped ceiling/soffit and the attic.



Air barrier is present between the dropped ceiling/soffit and the attic

### 3.3.1

## Dropped ceiling/soffit below unconditioned attic



Seams of air barrier not sealed.

Seams and penetrations of air barrier properly sealed

# Shafts, Chases, Soffits and Penetrations Shall be Sealed





# ENERGY STAR Qualified Homes, Version 3 (Rev. 06)

## Thermal Enclosure System Rater Checklist

5. Air Sealing	Must Correct	Builder Verified <sup>1</sup>	Rater Verified	N/A
5.1 Penetrations to unconditioned space fully sealed with solid blocking or flashing as needed and gaps sealed with caulk or foam				
5.1.1 Duct / flue shaft	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1.2 Plumbing / piping	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1.3 Electrical wiring	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1.4 Bathroom and kitchen exhaust fans	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1.5 Recessed lighting fixtures adjacent to unconditioned space ICAT labeled and fully gasketed. Also, if in insulated ceiling without attic above, exterior surface of fixture insulated to $\geq R-10$ in CZ 4 and higher to minimize condensation potential.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.1.6 Light tubes adjacent to unconditioned space include lens separating unconditioned and conditioned space and are fully gasketed <sup>22</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2 Cracks in the building envelope fully sealed				
5.2.1 All sill plates adjacent to conditioned space sealed to foundation or sub-floor with caulk, foam, or equivalent material. Foam gasket also placed beneath sill plate if resting atop concrete or masonry and adjacent to conditioned space <sup>23</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2.2 At top of walls adjoining unconditioned spaces, continuous top plates or sealed blocking using caulk, foam, or equivalent material	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2.3 Drywall sealed to top plate at all unconditioned attic / wall interfaces using caulk, foam, drywall adhesive (but not other construction adhesives), or equivalent material. Either apply sealant directly between drywall and top plate or to the seam between the two from the attic above.	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5.2.4 Rough opening around windows & exterior doors sealed with caulk or foam <sup>24</sup>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



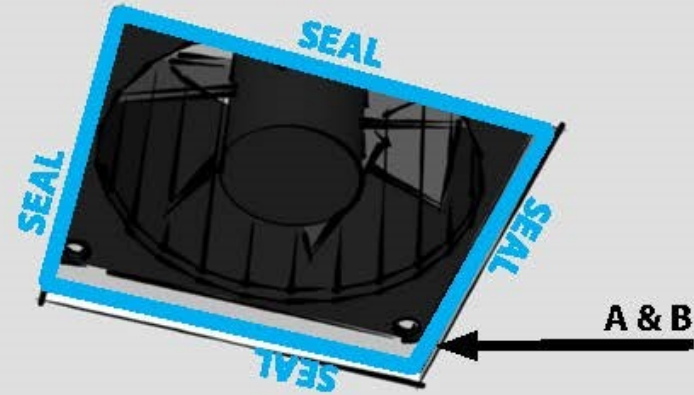
## SECTION 5. AIR SEALING

5.1 Penetrations to unconditioned space fully sealed with solid blocking or flashing as needed and gaps sealed with caulk or foam:

5.1.4 Bathroom and kitchen exhaust fans

**DETAIL 5.1.4****Bathroom and kitchen exhaust fans**

- A. Using a saw or drill, cleanly cut all penetrating holes no more than 1 inch larger in diameter than the penetrating object to allow for proper air sealing.
- B. Seal all gaps, and holes to unconditioned space with caulk or foam. Fibrous insulation is not an air barrier and cannot be used for sealing gaps.



**TRADES**  
**ELECTRICIAN**  
**HVAC TECHNICIAN**



## 5.1.4

# Bathroom and kitchen exhaust fans



Roughly cut hole that is larger than the fan making it difficult to seal..

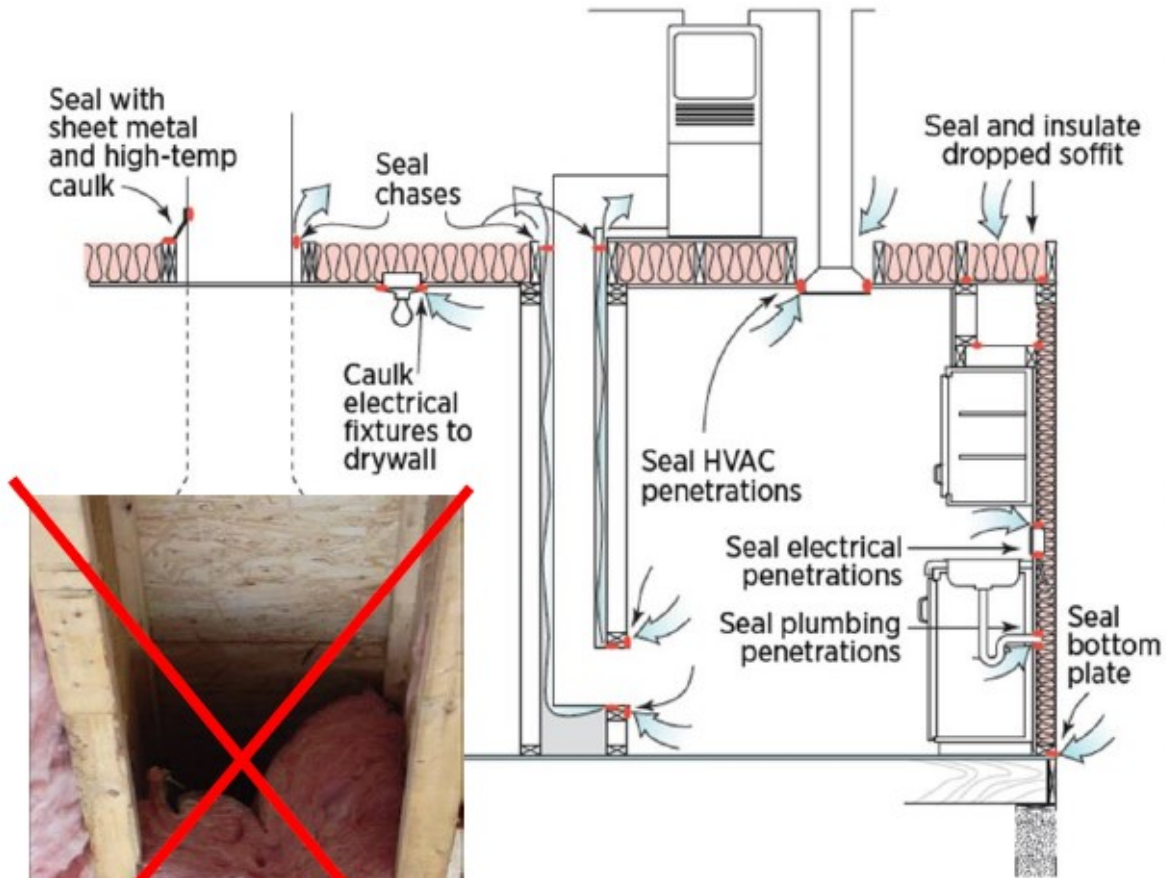


Cleanly cut and properly sized hole.

## 2

### Ceiling/attic

The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier sealed. Access openings, drop down stair or knee wall doors to unconditioned attic spaces shall be sealed.



**DETAIL 5.1.5**

**Recessed lighting fixtures adjacent to unconditioned space ICAT labeled and fully gasketed. Also, if in insulated ceiling without attic above, exterior surface of fixture insulated to  $\geq R-10$  in CZ 4 and higher to minimize condensation potential.**

- A. Install ICAT labeled recessed lighting fixtures.
- B. Seal all gaps, and holes to unconditioned space with caulk or foam.
- C. Install a proper trim kit with a gasket.



**TRADES  
ELECTRICIAN**

# 5.1.5

Recessed lighting fixtures adjacent to unconditioned space ICAT labeled and fully gasketed. Also, if in insulated ceiling without attic above, exterior surface of fixture insulated to  $\geq R-10$  in CZ 4 and higher to minimize condensation potential.



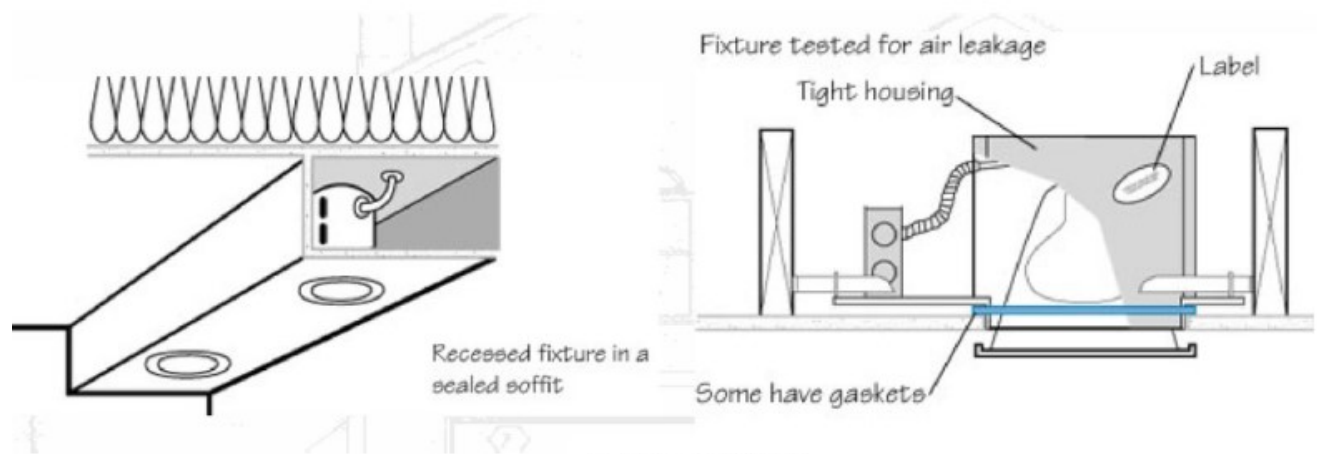
Non ICAT recessed light installed.



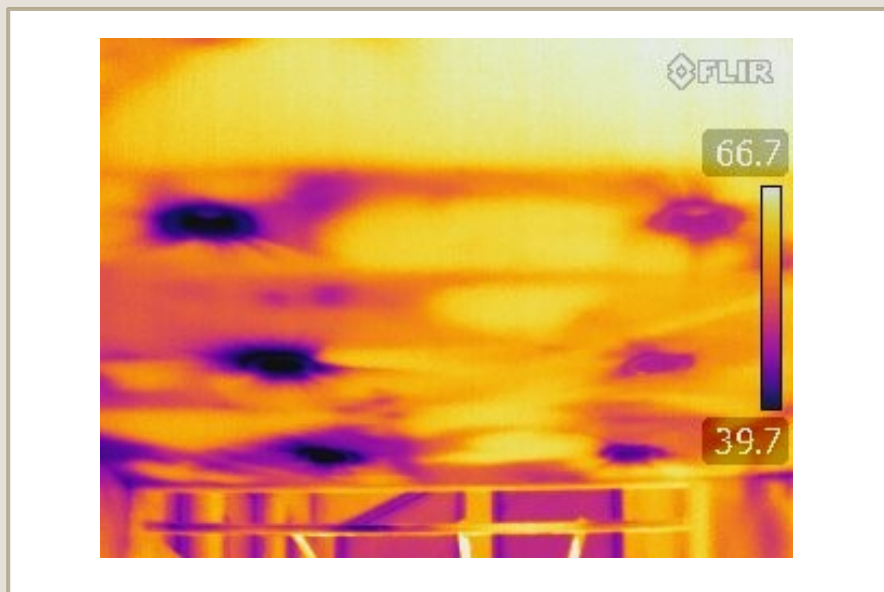
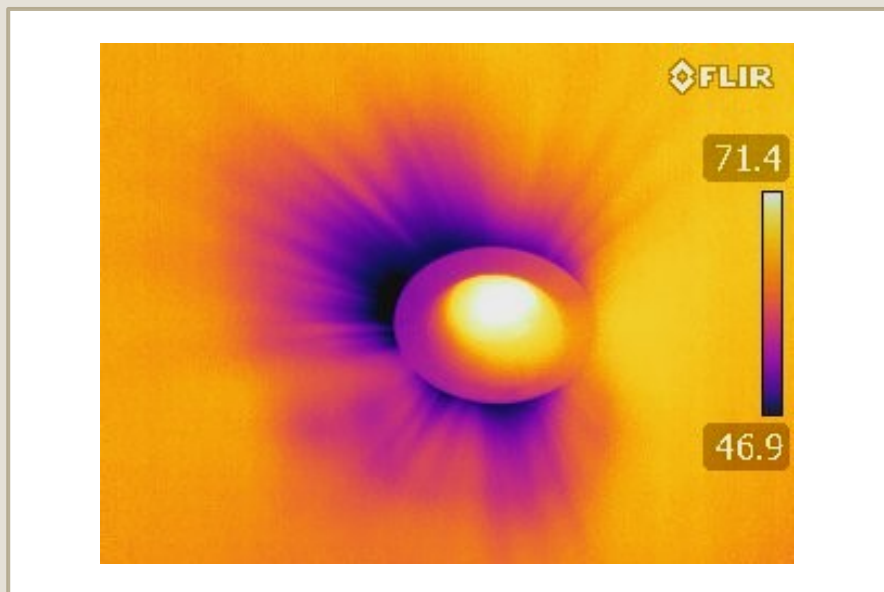
ICAT labeled recessed light with trim kit installed.

**11** Recessed lighting

Recessed light fixtures installed in the building thermal envelope shall be air tight, IC rated, and sealed to the drywall.



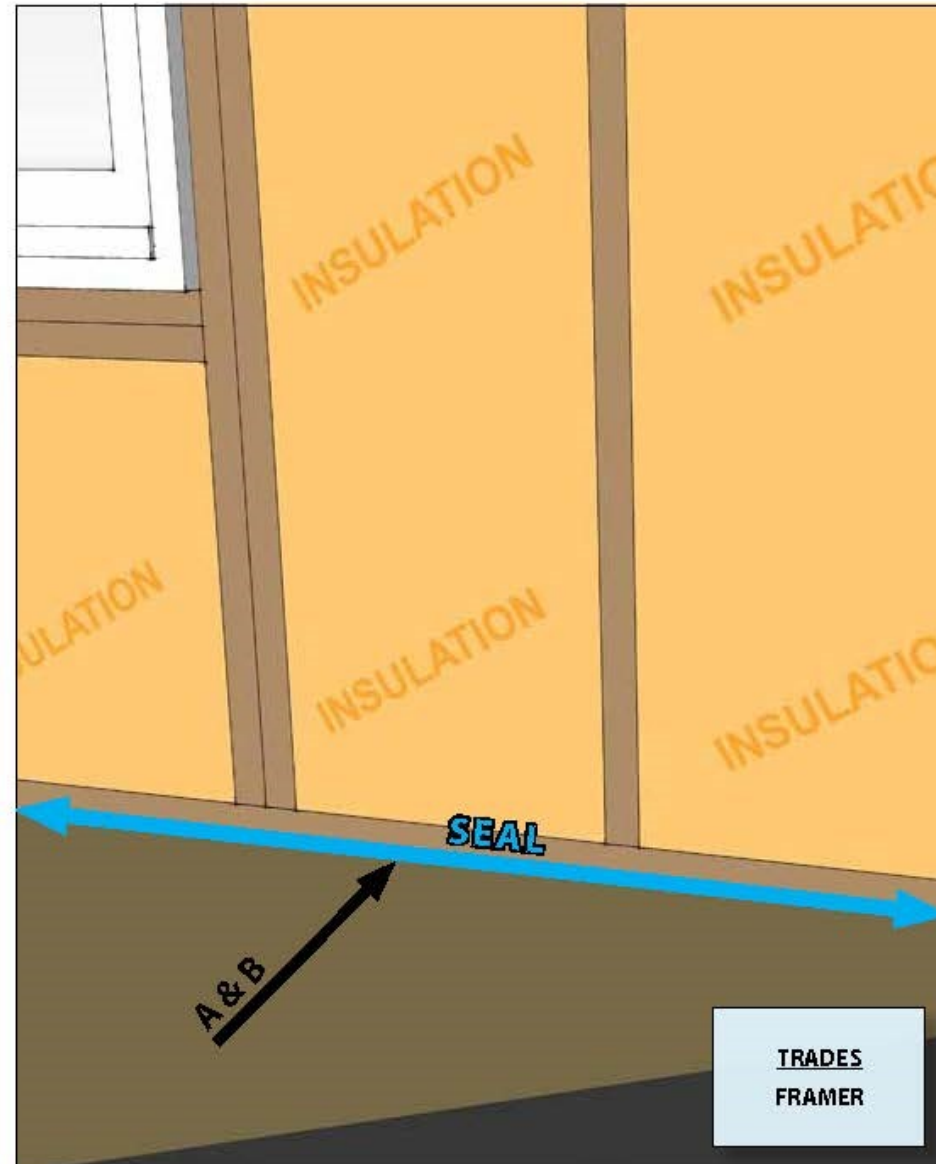
Source: ENERGY STAR



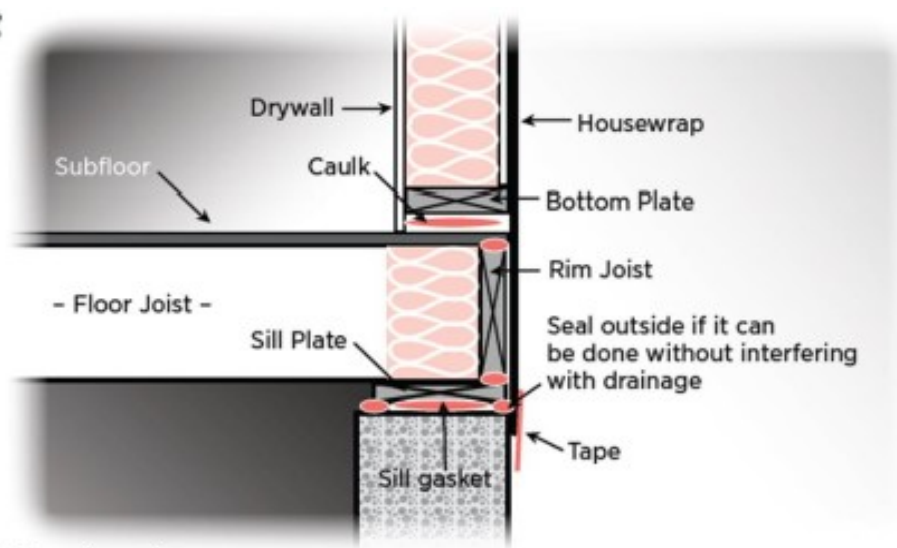
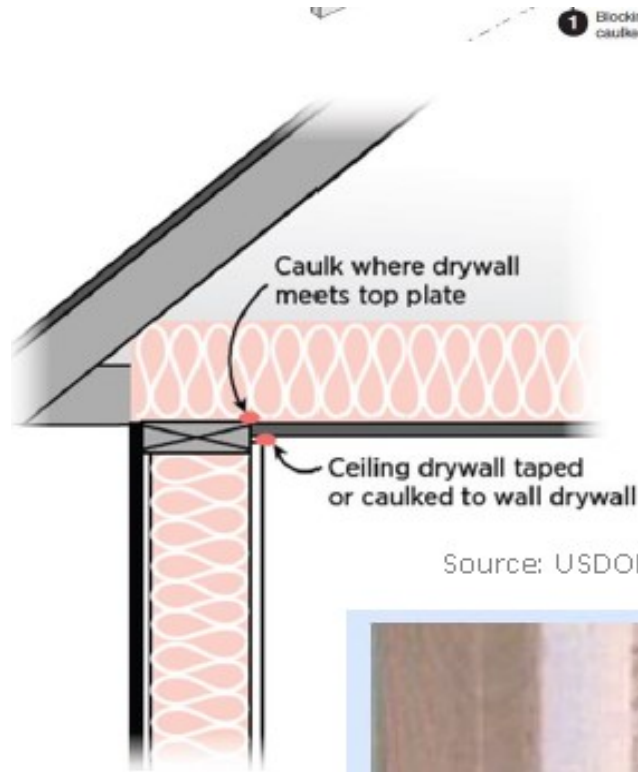
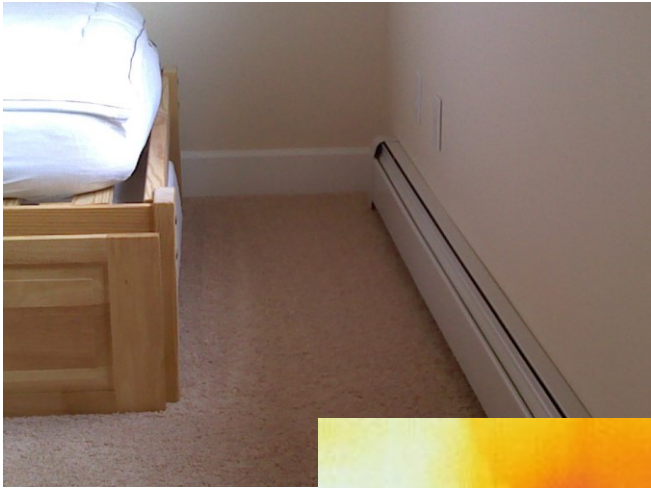
**DETAIL 5.2.1**

**All sill plates adjacent to conditioned space sealed to foundation or sub-floor with caulk. Foam gasket also placed beneath sill plate if resting atop concrete or masonry and adjacent to conditioned space**

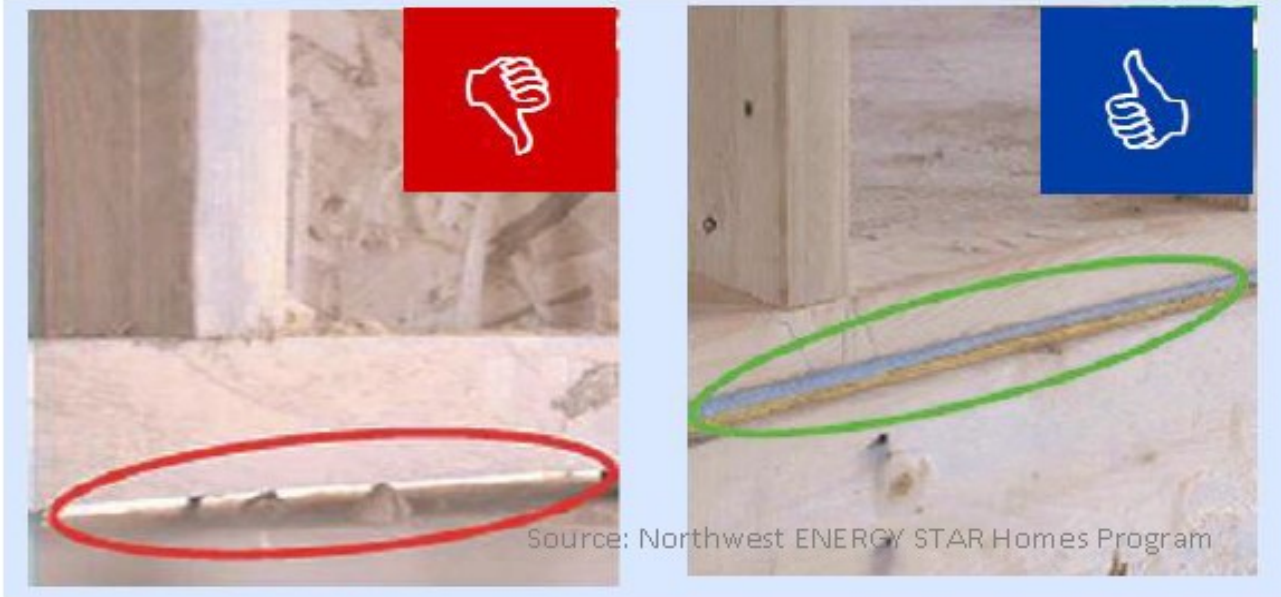
- A. Locate all sill plates of all exterior walls, common walls, and vertical members at foundation step downs.
- B. Install a gasket to prevent air leakage and seal all exterior wall sill plates to the sub-floor or foundation to prevent air leakage.



# 3 Walls



Source: USDOE Building America



Source: Northwest ENERGY STAR Homes Program

## 5.2.1

All sill plates adjacent to conditioned space sealed to foundation or sub-floor with caulk. Foam gasket also placed beneath sill plate if resting atop concrete or masonry and adjacent to conditioned space.



No foam gasket or air seal between sill plate and masonry foundation.



Foam gasket installed between sill plate and foundation.





## SECTION 5. AIR SEALING

### 5.2 Cracks in the building envelope fully sealed:

5.2.2 At top of walls adjoining unconditioned spaces,  
continuous top plates or sealed blocking using caulk, foam, or equivalent material

**DETAIL 5.2.2**

**At top of walls adjoining unconditioned spaces,  
continuous top plates or sealed blocking using caulk,  
foam, or equivalent material**

- A. Install a continuous top plate at all full height walls.
- B. Where there is no continuous top plate, install blocking and seal.



## 5.2.2

At top of walls adjoining unconditioned spaces, continuous top plates or sealed blocking using caulk, foam, or equivalent material



Wall from above without top plate or blocking installed.



Blocking installed and air sealed instead of continuous top plate.

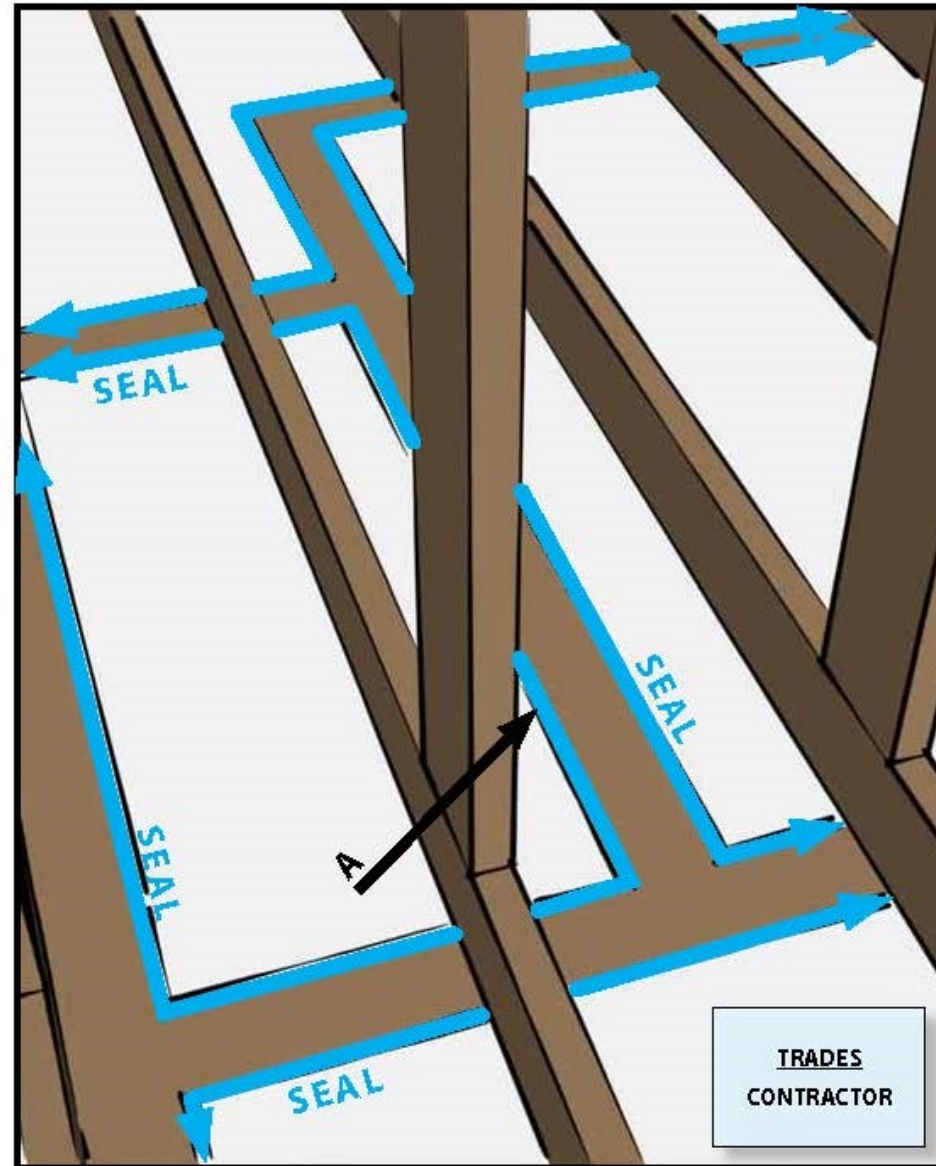
**DETAIL 5.2.3**

**Sheetrock sealed to top plate at all attic/wall interfaces using caulk, foam, or equivalent material. Either apply sealant directly between sheetrock and top plate or to the seam between the two from the attic above. Construction adhesive shall not be used**

- A. Before insulating the attic, seal all top plate to interior cladding connections with latex foam or caulk to stop air leakage between conditioned and unconditioned space.

**OR**

- B. Before installing drywall, use spray foam sealant or gasket product on top plate to air seal once drywall is installed. If this method is used, make sure foam/gasket remains intact during drywall installation.



## 5.2.3

Sheetrock sealed to top plate at all attic/wall interfaces using caulk, foam, or equivalent material. Either apply sealant directly between sheetrock and top plate or to the seam between the two from the attic above. Construction adhesive shall not be used



Top plate to drywall connection not sealed.



Top plate to drywall connection sealed from attic with foam.

## 5.2.3

Sheetrock sealed to top plate at all attic/wall interfaces using caulk, foam, or equivalent material. Either apply sealant directly between sheetrock and top plate or to the seam between the two from the attic above. Construction adhesive shall not be used



Top plate to drywall connection not sealed.

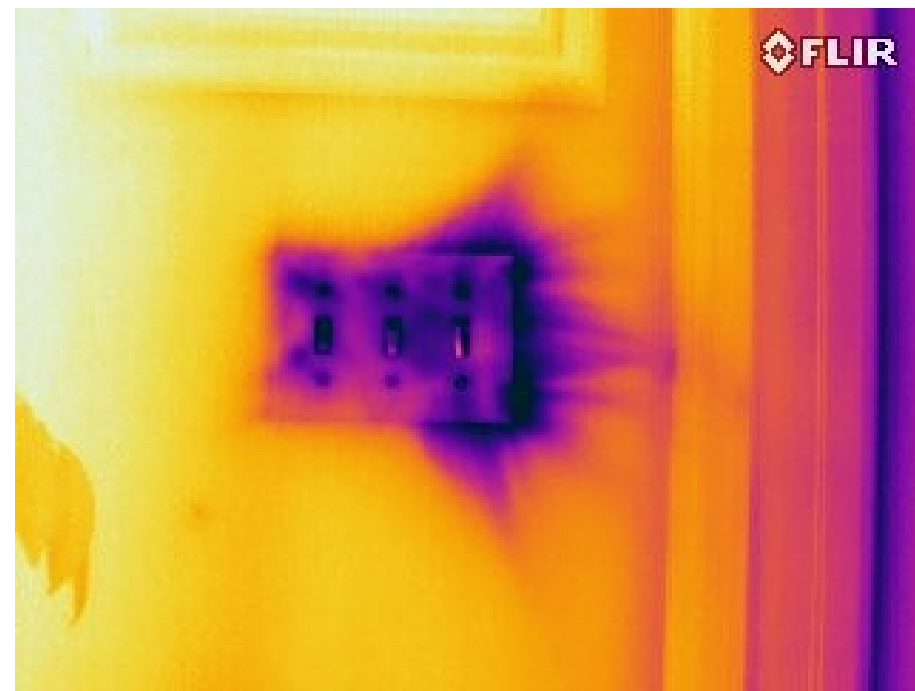
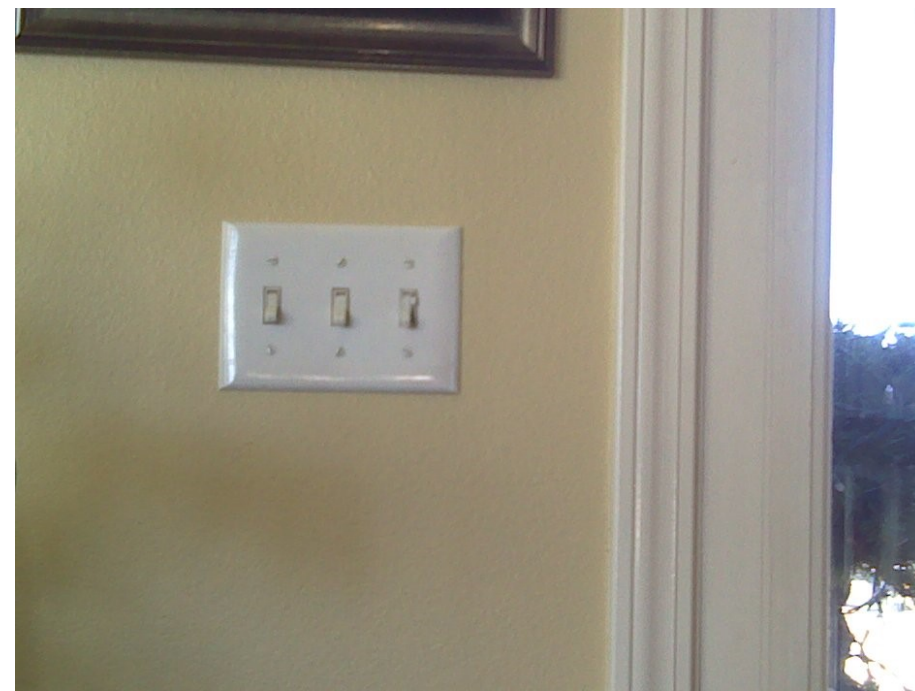
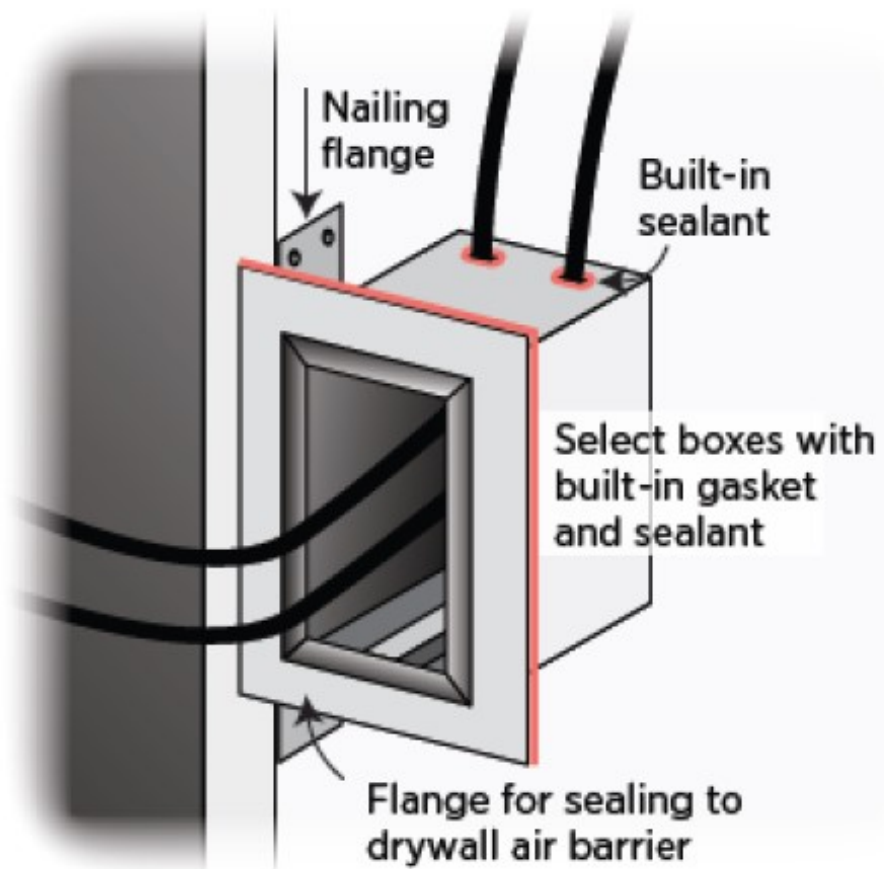


Top plate to drywall connection sealed from attic with caulk.

14

Electrical/phone  
box on exterior  
walls

The air barrier shall be installed behind electrical or communication boxes or air sealed boxes shall be installed.

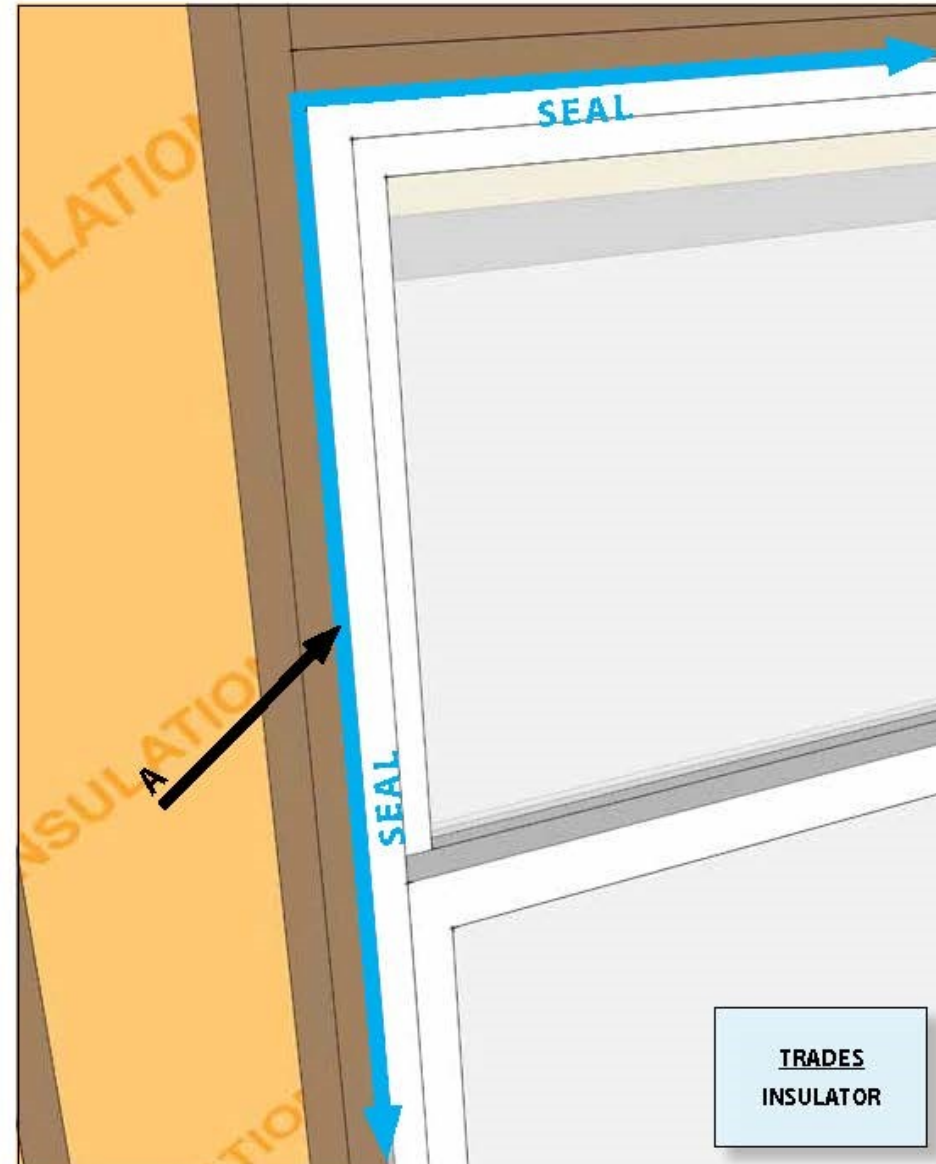


**DETAIL 5.2.4<sup>23</sup>****Rough opening around windows and exterior doors sealed with caulk or foam**

- A. Install backer rod or low-expansion foam in openings around windows and doors.
- B. Fibrous insulation is not an air barrier and cannot be used for sealing gaps.
- C. Avoid using typical expansion foam as it might interfere with the functioning of the window or door.

**FOOTNOTES**

23. In Climate Zones 1 through 3, stucco over rigid insulation tightly sealed to windows and doors shall be considered equivalent to sealing rough openings with caulk or foam.





## 5.2.4

# Rough opening around windows & exterior doors sealed with caulk or foam <sup>23</sup>



Rough opening around window not air sealed



Rough opening around window has been filled with backer-rod to air seal.

## 5.2.4

# Rough opening around windows & exterior doors sealed with caulk or foam <sup>23</sup>



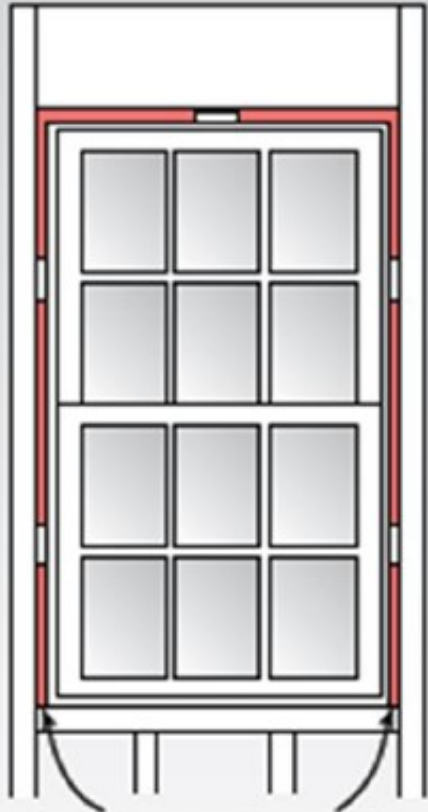
Fibrous insulation is not an air barrier and cannot be used to air seal openings.

Rough opening around window has been filled with low-expansion foam to air seal.

4

Windows,  
skylights and  
doors

The space between window/door jambs and framing and skylights and framing shall be sealed.



backer rod, caulk,  
or nonexpanding foam



Source: USDOE Building Energy Codes  
University



- 2 x Framed Code Build Construction
- EIFS Wall System
- Remote Wall System
- Integrated Wall System

# Wall Systems

# EIFS Wall Systems & Products

## NOTE:

- Thickness of the EPS will need to be increased in very cold climates to control temperature of condensing surface.

## REFERENCES

- 1 Lstiburek, J. W. (2006). *Water Management Guide*. Westford: Building Science Press Inc.
- 2 Lstiburek, J. (2008, 08 20). *BSD-104: Understanding Air Barriers*. [www.buildingscience.com](http://www.buildingscience.com).
- 3 Straube, J. (2009, 04 22). *BSD-014 Air Flow Control in Buildings*. [www.buildingscience.com](http://www.buildingscience.com).

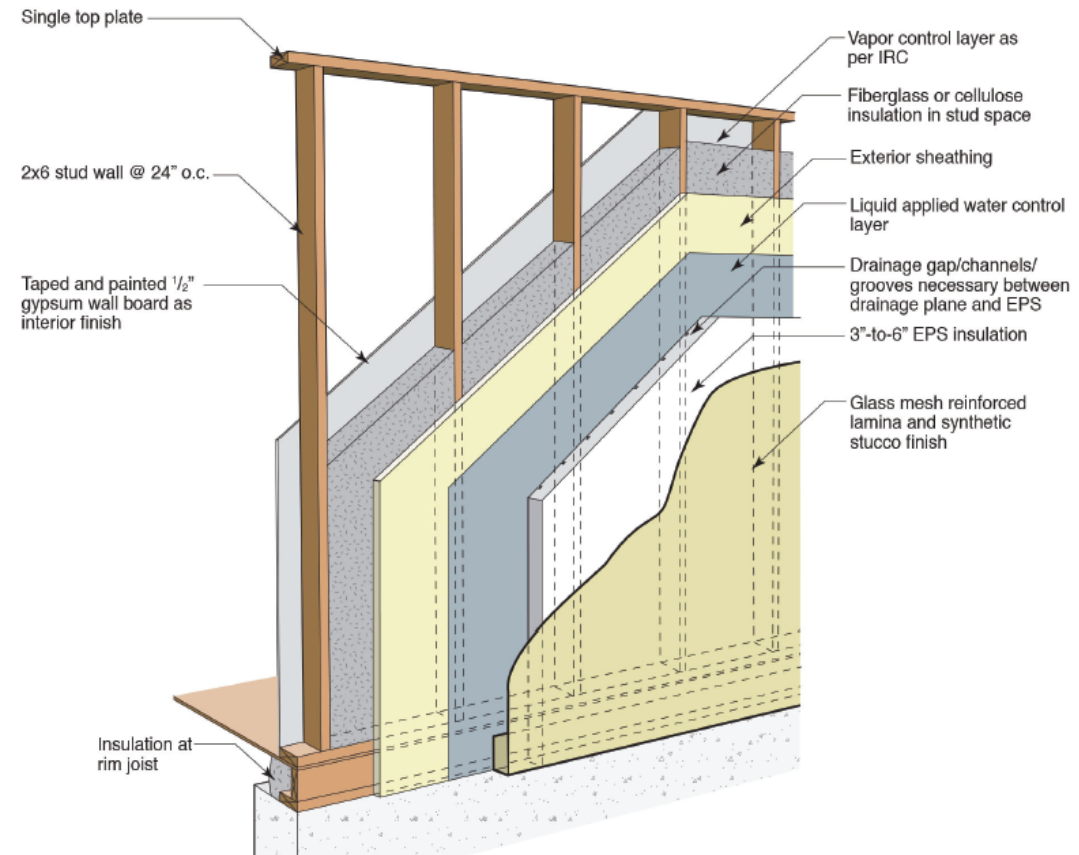
HIGH R-VALUE ENCLOSURE

# EXTERIOR INSULATION FINISH SYSTEMS (EIFS) WALL CONSTRUCTION

## EXTERIOR INSULATION FINISH SYSTEMS (EIFS) WALL CONSTRUCTION DETAILS

- 2x6 wood frame wall at 24" o.c.
- Fiberglass or cellulose cavity insulation
- Glass-faced gypsum sheathing
- Liquid applied water control layer
- Exterior EPS insulation
- Drainage gap/channels/grooves necessary between water control layer and EPS
- Stucco finish

<https://www.buildingscience.com/file/3697/download?token=4PZ6noLU>



## SUMMARY

This wall system is a durable and reliable choice regardless of the historical failures of this construction strategy. A better understanding of enclosure design and building science with drained and ventilated claddings and better design details have nearly eliminated the historical moisture related issues. This wall system has the appearance of a stucco finish, but with

# Fluid Applied Products

## Channeled Adhesive CI Design

Adhesively-applied, continuously insulated exterior wall cladding with a continuous air/water-resistive barrier

### System Description

Channeled Adhesive CI Design is a continuously insulated rainscreen wall cladding system. It features a SENERSHIELD fluid-applied air/water-resistive barrier, moisture drainage, up to R46 continuous exterior insulation, optional HI-IMPACT mesh and a wide range of finish options.

### Uses

Channeled Adhesive CI Design may be used in fire-resistance-rated construction and in any construction type (IBC Types I through V), when installed in accordance with BASF Wall Systems' instructions.

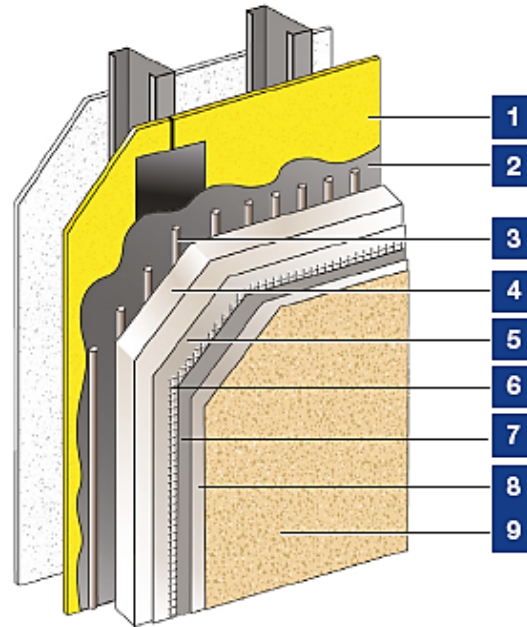
### Code Compliance

Document	Code Description
ICC-ESR 1878	2015 IBC, 2015 IRC
CCMC 13062-R	National Building Code of Canada 2015
Miami Dade NOAs	Meets Miami Dade hurricane requirements
ICC-ESR 2986 (Senershield-R)	Air/water-resistive barrier*
Air Barrier Association of America recognized (Senershield-R/-VB)	Can be used on projects where ABAA recognized air barriers are specified

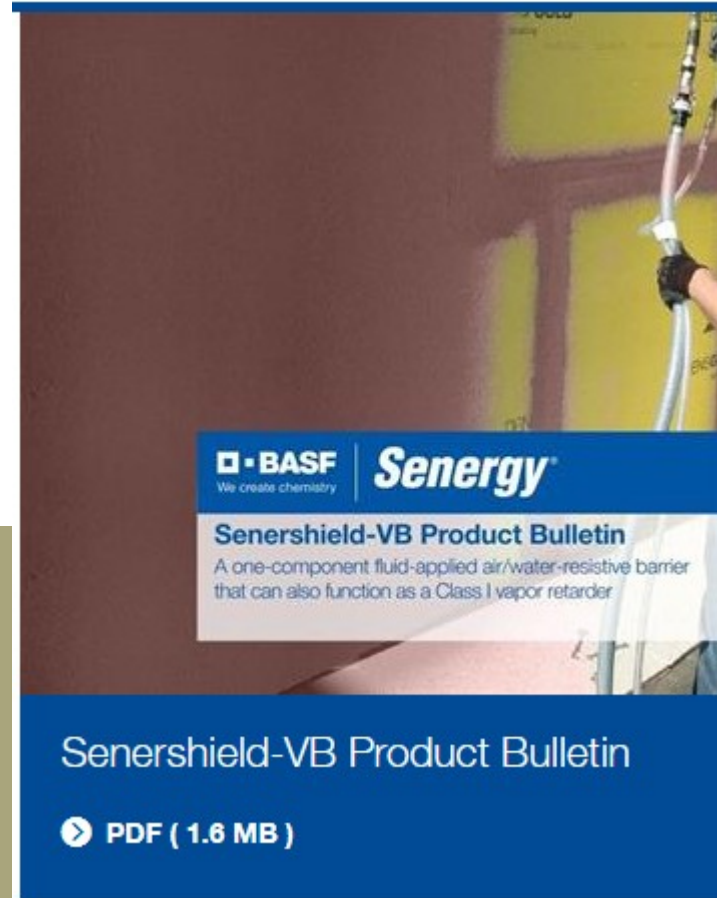
\*Senershield-R/-RS/-VB can be used behind all claddings where more than one wall system is specified, creating one continuous AWPB system. This is appropriate whenever Senergy Channeled Adhesive CI Design is used with other cladding types on a multi-clad building.

### Material Substitution

Material substitution will adversely affect system performance and will void all warranty coverage unless approved in writing by BASF Wall Systems.



1. Acceptable substrates:  
PermaBase<sup>®</sup> Cement Board and other cement boards conforming with ASTM C1325 (Type A - exterior); poured concrete/unit masonry; ASTM C1177 type sheathings, including Weather Defense<sup>™</sup> Platinum sheathing, GreenGlass<sup>®</sup> sheathing, eXP<sup>™</sup> sheathing, GlasRoc<sup>®</sup> sheathing, Securock<sup>™</sup> glass-mat sheathing, and DensGlass<sup>®</sup> exterior sheathing; DensElement (sheathing only), gypsum sheathing (ASTM C79/C1396); Exposure I or exterior plywood (Grade C/D or better); or Exposure I OSB; Huber Zip (sheathing only).
2. Senershield-R/-RS/-VB





# REMOTE

## A Manual

# Remote Wall Systems

# Remote Wall

## Exterior Membrane

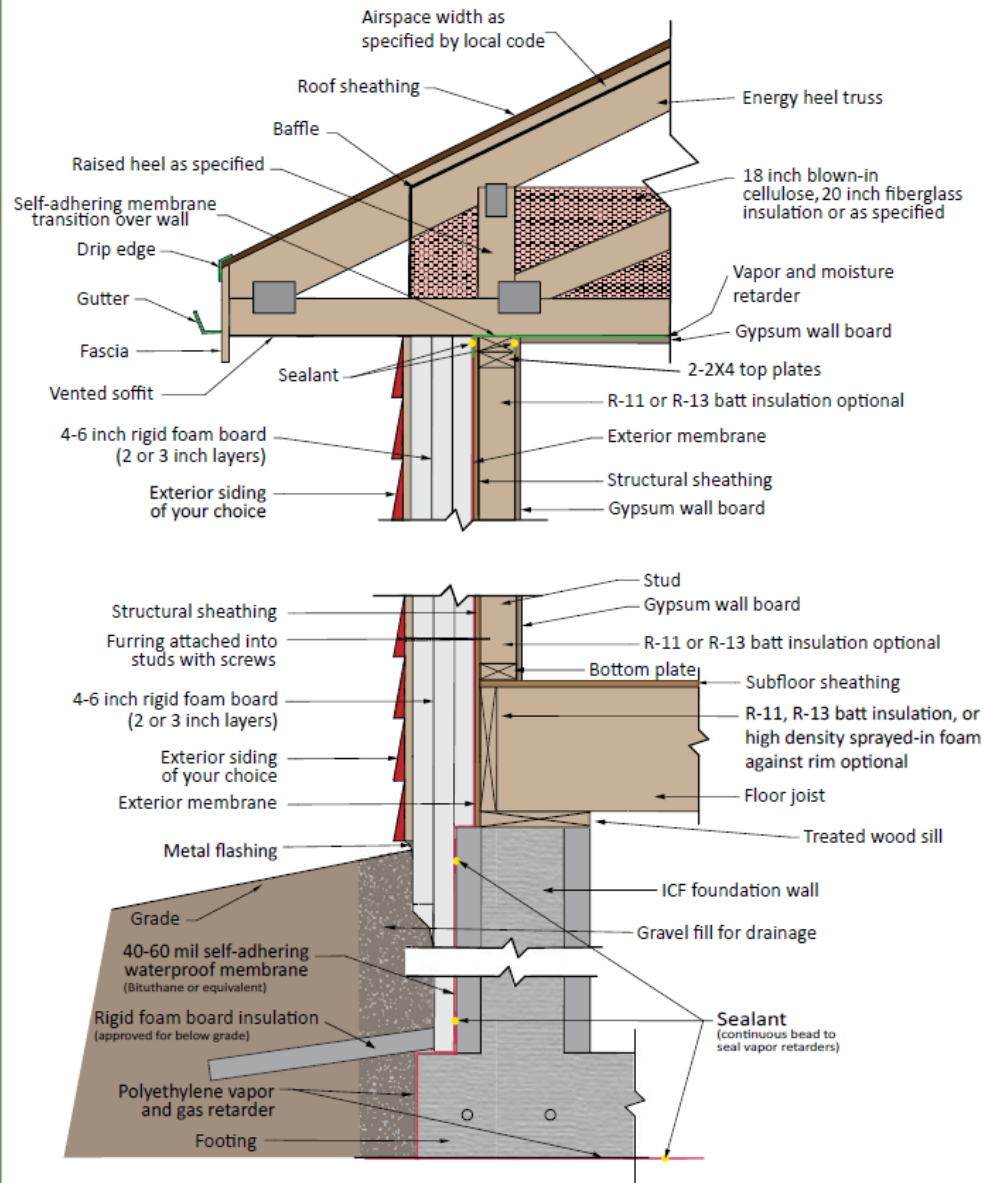


Image 19. Grace Bituthene® exterior membrane, one of several vapor retarder options

[http://cchrc.org/media/REMOTE\\_Walls.pdf](http://cchrc.org/media/REMOTE_Walls.pdf)

Jack Hébert





# Integrated Wall Systems

# Integrated Truss

**INSULATION:** SPRAY FOAM or CELLULOSE

**Description:** Prefabricated whole-house truss

**Assembly:** Basic wood frame construction

**Materials:** prefabricated super-structure, standard materials otherwise

**Logistics:** Transportable by road or barge. Air transport may be possible depending on design.

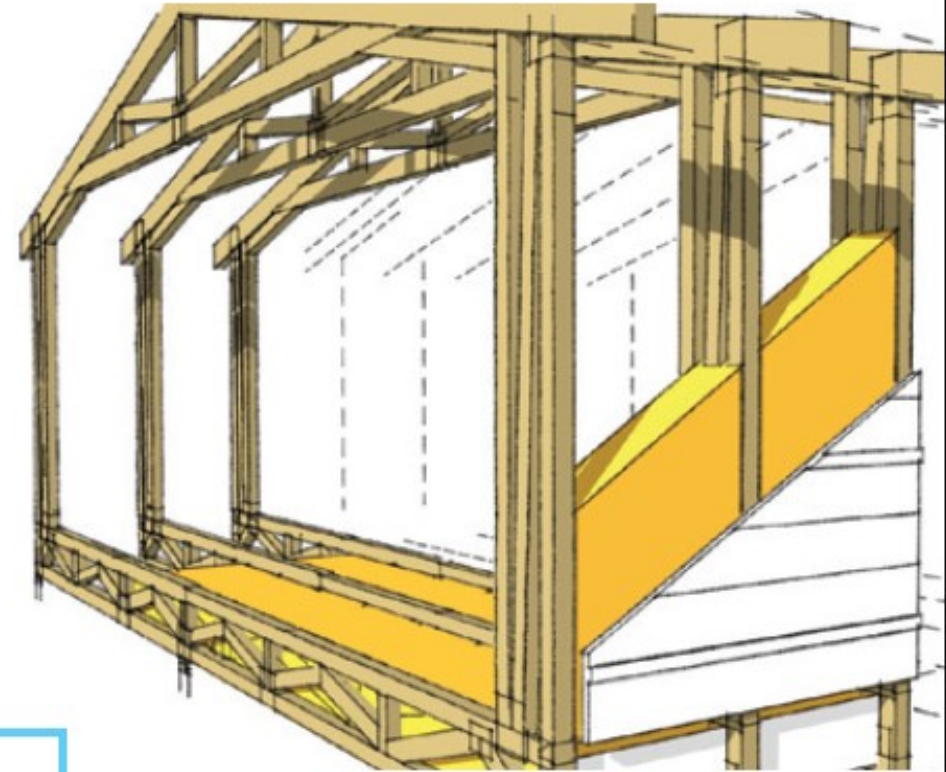
**Construction:** year round possible  
(potentially limited by use of spray foam)

## Cost Factors

**Increased costs:** Long shipping distances | logistic size restraints

**Decreased costs:** Road system builds | multiple units (economy of scale)

**Benefits of design:** Rapid construction time, less labor required

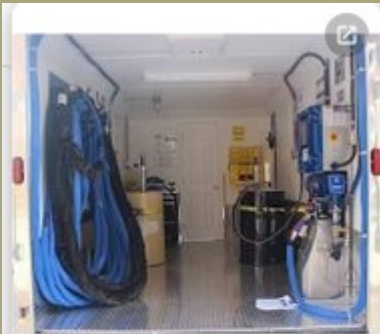


[http://cchrc.org/media/Atmautluak\\_Construction\\_Manual2013.pdf](http://cchrc.org/media/Atmautluak_Construction_Manual2013.pdf)



Fast assembly time

# Poly-urethane Foam Wall Systems & Products



**\$73,500.00**

SFS ProPAK 300D (SJ-30)  
Spray Foam Systems Rig -  
SPF Insulation Equipment  
Trailer - Graco E-30  
Reactor2  
Spray Foam Systems  
No tax



[https://www.sprayfoamsys.com/wp-content/uploads/2016/02/IMG\\_2705-2.jpg](https://www.sprayfoamsys.com/wp-content/uploads/2016/02/IMG_2705-2.jpg)

# CertaSpray® Extreme Winter™ Closed Cell Foam

## PRODUCT DESCRIPTION

**Basic Use:** CertaSpray® Extreme Winter™ Closed Cell Foam is a two-component closed cell spray foam with a zero-ozone-depleting HFC blowing agent. When CertaSpray A-side closed cell is mixed with CertaSpray B-side closed cell under pressure in a 1:1 volumetric ratio, they react and expand into a medium-density closed cell foam with an in-place core density of nominal 2.0 pcf.

**Benefits:** CertaSpray Extreme Winter Closed Cell Foam provides thermal insulation for the interior of homes and commercial buildings, and reduces air infiltration through the building envelope.



**Product Name** CertainTeed CertaSpray® Extreme Winter™ Closed Cell Foam

**Manufacturer** CertainTeed Corporation

**Address** 20 Moores Road  
Malvern, PA 19355

**Phone** 800-233-8990

**Website** [www.certainteed.com/insulation](http://www.certainteed.com/insulation)

## TECHNICAL DATA

### Applicable Standards

- ASTM C1029, Type I and Type II
- ICC-ES, AC-377 (ESR-3758)
- International Residential Code (IRC)
- International Building Code (IBC)
- International Energy Conservation Code (IECC)

## RECOMMENDED PROCESSING CONDITIONS

	VALUE
Preheater temperature, °F	120 – 135
Hose temperature, °F	120 – 135
Pressure, psi	1100 – 1500
A/B volumetric ratio	1/1
Cream time*, sec	1 – 2
Tack free time*,sec	3 – 6
Maximum thickness per pass, inches	3
Maximum installation thickness, inches	See application section

# Poly-urethane Foam Products

# New Innovated Products

# AEROBARRIER™

Breakthrough Envelope Sealing Technology



## 1) Setup

Equipment is set up at the job site. Conveniently transported by trailer, AeroBarrier install equipment is mobile and portable. The equipment includes a compressor, generator, blower door, emitters, hoses, and the AeroBarrier machine.



## 2) Prep

Prep the space. This includes taping or covering any areas that won't be sealed. Emitters are then set up throughout the area to be sealed.



## 3) Pressurize

Pressurize the space with the use of a blower door. A computer does the rest, including the control of temperature, pressure, humidity, and distribution of sealant during the process.

<https://constructioninstruction.com/video/aerobarrier-overview-video/>

# Whole Building Air Leakage Testing is a Commissioning Test of the Air Barrier System

## Test Results at 50 Pascals:

Airflow (cfm50)	3475 ( +/- 0.5 %)
Air Changes per Hour 50 (1/h)	7.26
cfm50/ft <sup>2</sup> Floor Area	1.3038
cfm50/ft <sup>2</sup> Surface Area	0.729

**2014 Construction (Non-BEES Compliant)**  
**2,665 sqft Floor Area**

## Leakage Areas:

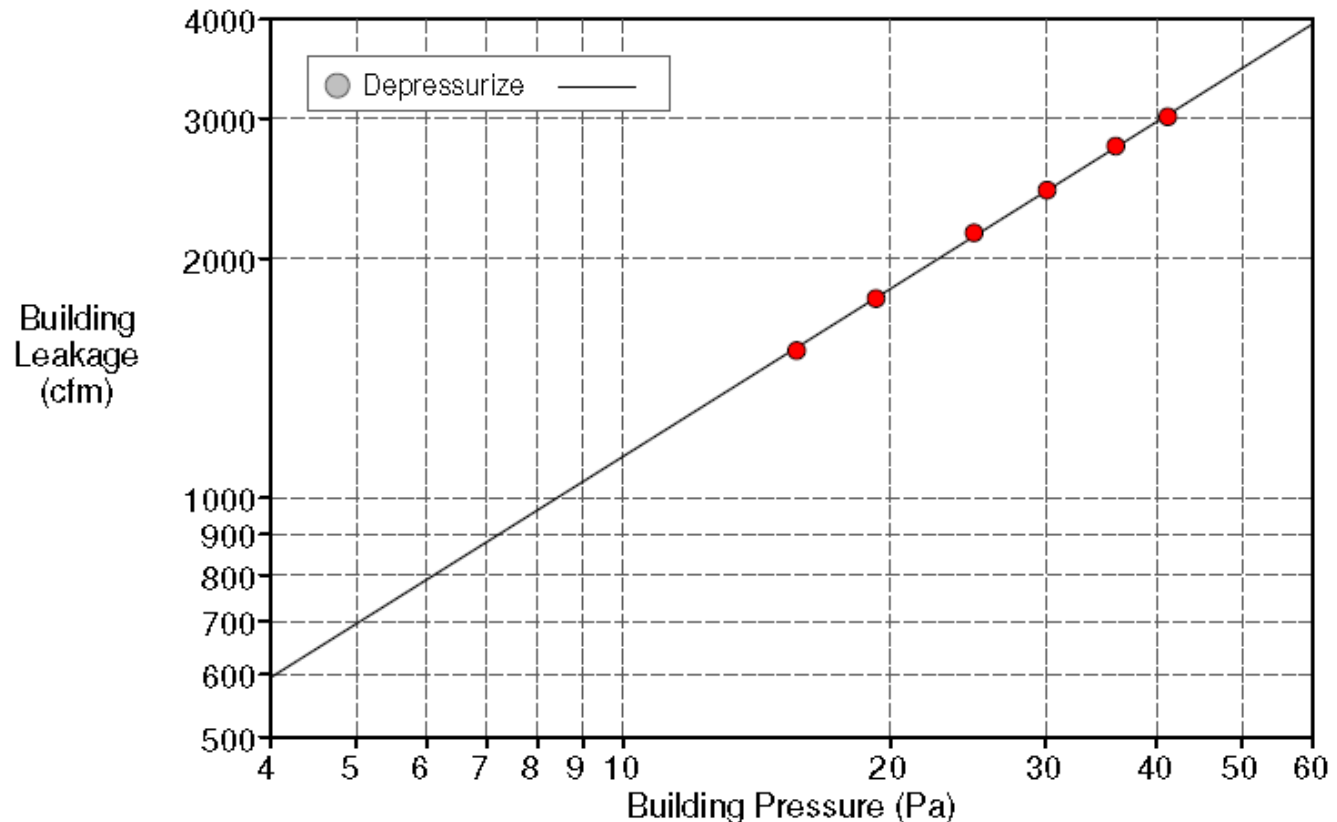
331.8 in<sup>2</sup> ( +/- 1.1 %) Canadian EqLA @ 10 Pa  
169.0 in<sup>2</sup> ( +/- 1.9 %) LBL ELA @ 4 Pa

## Building Leakage Curve:

Flow Coefficient (C) = 226.2 ( +/- 3.3 %)  
Exponent (n) = 0.698 ( +/- 0.009 )  
Correlation Coefficient = 0.99963

Test Standard:  
Test Mode:

CGSB  
Depressurization



This builder did  
his home work.

If you don't test  
it, You don't  
know!

#### Test Results at 50 Pascals:

Airflow (cfm50)	318 ( +/- 0.4 %)
Air Changes per Hour 50 (1/h)	0.97
cfm50/ft <sup>2</sup> Floor Area	0.1685
cfm50/ft <sup>2</sup> Surface Area	0.0696

**2018 Construction**  
**1885 sqft Floor Area**

#### Leakage Areas:

31.3 in<sup>2</sup> ( +/- 2.2 %) Canadian EqLA @ 10 Pa or 0.0069 in<sup>2</sup>/ft<sup>2</sup> Surface Area  
16.2 in<sup>2</sup> ( +/- 3.5 %) LBL ELA @ 4 Pa or 0.0036 in<sup>2</sup>/ft<sup>2</sup> Surface Area

#### Building Leakage Curve:

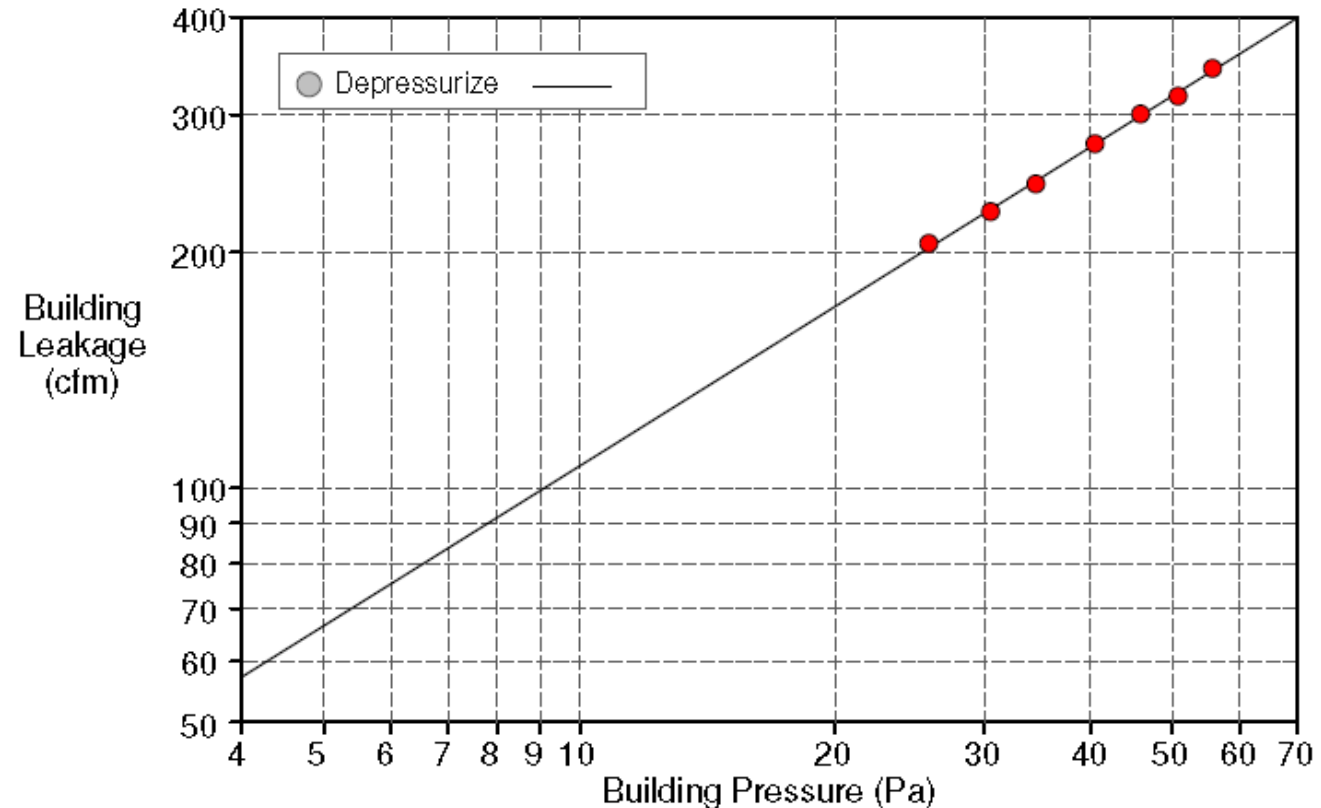
Flow Coefficient (C) = 22.3 ( +/- 5.5 %)  
Exponent (n) = 0.679 ( +/- 0.015 )  
Correlation Coefficient = 0.99884

Test Standard:

CGSB

Test Mode:

Depressurization



# Thank you

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## References:

<https://basc.pnnl.gov/resources/thermal-bypass-checklist-guide>

<https://www.buildingscience.com/>

<https://www.senergy.basf.com/en/products>

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