Chapter 2: Heating Envelope Building Measures

2.1 Heating Envelope Insulation

The building heating envelope comprises those surfaces that function as the thermal boundary between conditioned and unconditioned spaces. These surfaces may include, but are not limited to, exterior walls, attics, foundations, and exposed floors. Insulation reduces heat transmission by slowing conduction, convection, or radiation through the building envelope. The various insulating materials in the building make up the *thermal boundary* — the boundary that separates conditioned space from unconditioned space. Airtight materials that cover the walls, floor, and ceiling to prevent air movement form the *pressure boundary*. The thermal and pressure boundaries should be as continuous as possible and aligned properly so the insulation works effectively. The pressure boundary must be addressed before proceeding with work on the thermal boundary except in circumstances where both pressure and thermal boundaries are addressed at the same time, through measures such as dense-pack insulation. See *Chapter 1 – Section 1.5.3* for information on how to address the pressure boundary. All heating envelope building measures should be installed to meet a minimum expected service life of 20 years.

When Insulation is installed, a dated insulation certificate is provided to the building owner that includes:

1. Insulation type
2. Coverage area
3. R-Value
4. Installed thickness and settled thickness
5. Number of bags installed in accordance with manufacturer instructions

2.2 Attic and Roof Insulation

2.2.1 Pre-insulation Attic and Roof Insulation Prep

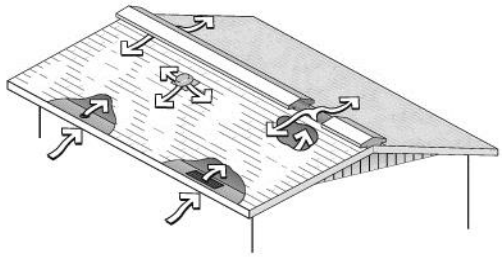
Perform these preparatory steps and safety procedures before installing attic insulation:

1. Vent all exhaust appliances to the outdoors, as specified in *Chapter 3 – Section 3.13* using a dedicated exhaust termination. Seal and insulate exhaust ducts to R-8 to prevent condensation inside the duct. Check all fans for proper backdraft-damper operation. Repair or replace the damper, or the entire fan assembly, if the damper does not operate freely.
2. Isolate insulation a minimum of 2 inches from masonry chimneys and per manufacturer instruction for metal vents, using rigid damming material. Do not allow insulation to spill into clearance spaces.
3. Repair roof leaks and address other attic-related moisture problems before insulating attic.

4. Confirm all wire splices are enclosed in electrical junction boxes. Mark all junction boxes that will be covered with insulation with a sign or flag.
5. When not removing knob-and-tube wiring, maintain a 3-inch clearance from insulation around live knob-and-tube wiring using appropriate materials. See *Electrical Safety in Chapter 5 – Section 5.5*.
6. Remove or perforate existing vapor retarders on the cold side of the insulation.
7. Check the manufacturer's instructions to determine if fixtures can be covered with insulation. If fixtures cannot be covered with insulation, or if Insulation Contact (IC)-rating is unknown, keep all insulation three inches from these fixtures. Fasten shields or covers securely to the rafter or ceiling joist so that they maintain three inches of clearance and don't move or collapse.
8. If heating-system ductwork runs through the attic, seal and insulate as appropriate (see *Duct Leakage and Duct Insulation in Chapter 3 – Sections 3.4.2 and 3.4.3*). Do not apply duct insulation to ducts that will be surrounded by R-11 or more of loose-fill insulation.
9. If the attic is used for storage, eliminate or reduce the amount of storage area with the customer's approval. Storage area must maintain a minimum of R-19 for attic insulation. Build an insulation dam around the area. If items are present during insulation, temporarily either remove items from area or cover with plastic or a tarp.
10. Install depth markers for installed insulation every 300 square feet of attic area, with the measurement beginning at the air barrier.
11. When a whole-house fan is encountered in a home, construct a box around the fan at a height to protect the fan housing and motor from insulation. Insulate the exposed sides and top of the box assembly to the same R-value as the adjoining insulation. Use the appropriate adhesive or mechanical fasteners.
12. Consider placing a fiberglass batt on top of the exhaust-fan housing in the attic before blowing insulation. The batt will prevent loose-fill insulation from spilling into the home if the fan is replaced in the future.

2.2.2 Attic Ventilation

Install attic ventilation when it is needed. When installing ventilation, there should be an equal distribution of vent area across all attic areas whenever possible. Split the net free area of attic ventilation equally between high and low venting, if possible. Consult state and local building codes for requirements on the minimum amount of attic ventilation.



Low and high attic ventilation: A moderate amount of ventilation creates air exchange with outdoors.

Gable Vents

Install gable-end vents as high in the gable end as possible and above the final level of the attic insulation. Build a dam in front of existing gable vents if insulation comes up to the bottom of the vent.

Roof Vents

Install the top flashing of the roof vents under asphalt shingles and mechanically fasten and seal with plastic roof cement or with products specifically designed for this purpose. Center all roof vents between rafters. Where possible, mount vents no closer than 12 inches (measured vertically) from the ridge of the roof of the attic insulated.

Soffit Vents

When soffit venting is required, use products specifically designed for this purpose. Eave chutes allow the installation of the maximum amount of insulation over the exterior top-plate. Chutes can also prevent wind-washing of the insulation, which degrades the insulation's R-value. Install eave chutes as necessary to promote sufficient ventilation of the attic.

Mechanically fasten eave chutes at the top, and install blocking at the base to prevent insulation from spilling over into the soffit area. In rafter cavities where a chute is not installed, make sure the cavity is blocked with fiberglass batts or a rigid barrier to prevent spillover into the soffit area. Chutes must be long enough to extend above the final insulation level.

Soffit chute: Allows installation of maximum amount of insulation in this cold area. Also prevents wind washing and airway blockage by blown insulation.

2.2.3 Attic Accesses, Walk-up Stairways, and Doors

Attic Accesses

Perform these tasks to address attic accesses, walk-up stairways, and doors prior to insulation:

1. Insulate accessible attic accesses to the R-value of the adjacent attic insulation or to the maximum structurally allowable, whichever is lower. Permanently attach the insulation and ensure it is in complete contact with the air barrier. Access must be operable, weather-stripped, and air-sealed.

2. Install durable damming material to maintain the R-value of the attic insulation up to the access, allow repeated access to the attic, and to prevent loose-fill insulation from entering the home.
3. Post warnings in access to attics with asbestos-containing materials or vermiculite. See Chapter 9 – Health & Safety of the Wisconsin Weatherization Program Manual for more information about asbestos.

Walk-Up Stairways and Doors

Establish a continuous insulation and air barrier around or over the top of an attic stairway. If the attic is accessed using a stairwell and standard vertical door, there are two methods for treatment.

Method 1

Insulate the walls of the stairwell, as well as beneath landings, stair treads, and risers. Insulate and weather-strip the back of the door to the R-value of the adjacent wall insulation or the maximum structurally allowable, whichever is lower.

When planning to insulate stairwells, investigate for barriers, such as fire blocking, that might prevent insulation from filling cavities. Consider which passageways may lead to other areas where insulation should not be installed, such as closets or chimney chases. Balloon-framed walls and deep stair cavities complicate this measure.

Method 2

Establish the thermal boundary at the ceiling level by installing an insulated and air-sealed horizontal hatch at the top of the stairs. Insulate the hatch to the R-value of the adjacent attic insulation or the maximum structurally allowable, whichever is lower.

Insulating and Sealing Retractable Attic Stairways

Building an insulated box is a good solution to insulating and sealing this weak point in the thermal boundary. Insulate the box and the cover to an R-value equal to the attic insulation level, or to the highest R-value structurally allowable. Use care in establishing a continuous thermal boundary when air sealing and insulating around the hatch opening.

2.2.4 Calculating Attic Loose-Fill Insulation

Install loose-fill attic insulation at a uniform depth to attain proper coverage (bags per square foot) and proper R-value at the manufacturer's specified installed thickness. Follow the manufacturer's instructions in order to achieve the correct density to meet the required R-value.

Loose-fill insulation always settles, and the manufacturer does account for settling in the listed minimum installation thickness charts. The installed thickness of cellulose decreases by 10 to 20 percent due to settling, and the installed thickness of blown fiberglass decreases by 3 to 10 percent. See *Appendix A-3* for the calculation of density and the number of bags needed to achieve the desired R-value at the settled density.

2.2.5 Installing Blown-in Attic Insulation

Blown insulation is preferred over batt insulation because blown insulation forms a seamless blanket. Blowing attic insulation at the highest structurally allowable density helps minimize settling and reduces convective currents within the insulation.

Follow these steps when installing loose-fill attic insulation:

1. Fill the edges of the attic first, near the eaves or gable end and work back toward the attic hatch. Ensure proper insulation density over the exterior top-plates.
2. Install insulation to a consistent depth. Use a stick to level the insulation if necessary.
3. Perform a bag count while blowing to confirm the proper depth and density of insulation is installed.
4. Avoid "fluffing," and maintain an adequate density by moving as much insulation as possible through the hose with the available air pressure. The more the insulation is packed together in the blowing hose, the greater its installed density will be.
5. Fill floored attic cavities to a higher density to minimize settling, if no electrical or material hazards are present. Install dense-packed or maximum structurally allowable density insulation in floored attic cavities when hidden bypasses have not been addressed by other methods.
6. Add additional insulation over floored attics not used for storage, as needed to achieve the specified R-value.

2.2.6 Installing Attic Batt Insulation

Follow these steps when installing fiberglass batts horizontally in the attic:

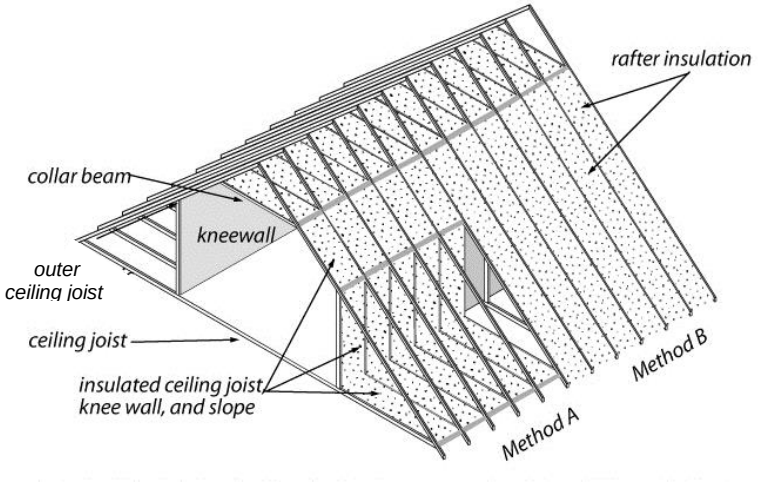
1. Install un-faced fiberglass-batt insulation. Cut batts carefully to ensure a tight fit against the ceiling joists and other framing.
2. Install two layers of batt insulation at a right angle to each other. This practice minimizes voids and produces better thermal resistance.

2.2.7 Installing Attic Insulation in 1½ Story Homes (Finished Attics)

Finished attics in 1½-story homes require special care when installing insulation. They often include four separate attic sections requiring different sealing and insulating methods:

Collar beam: The attic at the top of the building, which runs between and connects the two roof rafter attics.

Roof rafter: The cavities between the ceiling and the roof. The roof-rafter section that runs between the collar-beam attic and the top of the knee wall is sometimes referred to as the "slope" or "slant."



Finished attic: This illustration depicts two approaches to insulating a finished attic. Either, A) insulate the kneewall and outer ceiling joist, or B) insulate the rafters. Method A reduces the size of the heating envelope, while Method B results in less surface area exposed to unconditioned air.

Knee wall: The short wall between the living area and the outside structural wall of the building. The space created behind the knee wall is often used for storage.

Outer ceiling joist: Flat attic surface located above the first-floor living area.
Follow these methods when insulating finished attics:

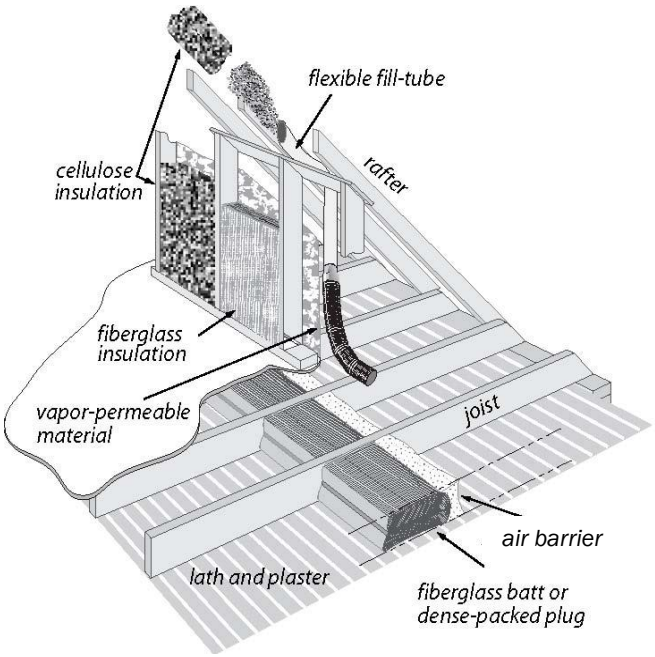
Method A

Method A treats the space behind the knee wall as *unconditioned* attic space. The thermal boundary includes the collar beam, the roof rafter, the knee wall, and the outer ceiling joist.

Follow these steps to treat the attics using ***Method A***:

1. Seal and carefully insulate built-in closets, dressers, or cabinets that protrude into the thermal boundary through the knee wall. Two-part foam can be effective at sealing and insulating these areas from inside the knee wall attic. See *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.
2. Create an airtight, permanent seal in the floor-joist space under the knee wall. Insert pieces of rigid board insulation, drywall, or ductboard in between each joist, and seal the perimeter of each piece with one-part foam; or by inserting a fiberglass batt into the cavity and spraying its face with two-part foam, or by using the ***Bag Method*** to blow a tight plug of dense-packed cellulose into the joist cavities.

To use the ***Bag Method***: place a plastic or mesh bag over the end of the fill tube and insert the tube and bag into the cavity. While holding on to the bag, start blowing insulation into the bag until full, then push the remaining part of the bag into the cavity. The bag will limit the amount of insulation it takes to plug this area.



Finished attic best practices: Air sealing and insulation combine to dramatically reduce heat transmission and air leakage in homes with finished attics.

3. Ensure insulation coverage is adequate where the knee wall meets the roof rafter and where the roof rafter meets the collar beam.
4. Insulate the roof rafters using dense-packed insulation. The roof rafters can be insulated from either the collar-beam attic or the outer-ceiling-joist attic. Ensure the opposite end has a barrier installed. Alternatively, dam both ends of each cavity and blow the roof rafters from the interior, like interior wall insulation. See *Dense-Packed Wall Insulation from the Interior in Chapter 2 – Section 2.3.5.*
5. Insulate knee walls using dense-packed insulation, fiberglass batts, or two-part foam. If dense-packing the knee walls, prepare them for blowing by fastening a vapor-permeable material to the cold side of the knee wall studs with reinforcement as needed.

6. When insulating knee walls with batt insulation, use appropriately sized batts to fit into the stud cavities.
7. Cover existing and/or installed fiberglass-batt insulation with a vapor-permeable material to prevent wind wash. Wrap or seal the vapor-permeable material around the studs at each end to prevent air movement behind the material. If a second layer of batt insulation leaves the studs inaccessible, fasten the vapor-permeable material to the roof rafters and deck at the top and to the floor at the bottom of the wall.

8. Insulate attic-access panels in the knee wall to the R-value of the adjacent knee wall insulation, or to the maximum structurally allowable, whichever is lower. Operable panels must be weather-stripped and must close with a tight seal. Vertical access panels require mechanical fasteners to maintain a tight seal.
9. Install a dam if needed to maintain the insulation's R-value near the access and to prevent loose-fill outer-ceiling-joist insulation from spilling into the living area. Secondary access panels in a knee wall may be sealed permanently, with the building owner's approval.
10. Follow steps in *Insulating Attics with Limited Accessibility in Chapter 2 – Section 2.2.8* for insulating the collar beam and outer ceiling joist attics.

Method B

Method B treats the attic space behind the knee wall as *conditioned* space. The thermal boundary is located at the roof deck and at the gable-end walls.

Follow these steps to treat the attics using ***Method B***:

1. Create an airtight, permanent seal in the joist space over the top of the first-floor exterior top-plate. This can be done by inserting pieces of rigid board insulation, drywall, or ductboard and foaming the perimeter of each piece with one-part foam; or by inserting a fiberglass batt into the cavity and spraying its face with two-part foam; or by using the ***Bag Method*** to blow dense-packed cellulose into the joist cavities. See ***Method A*** above for information about the ***Bag Method***. See the *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.
2. Air seal along the gable-end walls. Since the attic will become conditioned space, do not air seal at the floor of the outer ceiling joist, or at the floor-cavity key juncture beneath the knee wall.
3. Ensure insulation coverage is adequate and continuous where the roof rafter meets the outer ceiling joist and exterior top-plate.
4. Insulate the roof rafters and gable ends.
    a. Dense-pack insulation method:
        i. Existing sheathing: Drill holes and install dense-pack insulation using tubing method. Patch all drilled holes. The roof rafters can be insulated from the collar-beam attic using the tubing method.

ii. Exposed studs or rafters: If the cavities are to be dense-packed, prepare them for blowing by fastening a *non*-vapor-permeable material on the warm side of the rafters with reinforcement, as needed. Seal the edges to achieve a continuous vapor retarder. Blow the cavities from the outer-ceiling-joist attic through holes cut in the *non*-vapor-permeable material. Patch all cut holes. The roof rafters can be insulated from the collar-beam attic using the tubing method.

b. Batt insulation method: If batt insulation is installed, cover it with a vapor retarder. Air-seal the material, since it will now act as the primary pressure boundary.

c. Two-part foam method: If two-part foam is installed, do not install a vapor retarder, since two-part foam acts as both insulation and as an air seal. Typically, two-part foam insulation costs more than installing dense-packed cellulose or air sealing and then installing batts. If the side attic is to remain accessible, the foam must be covered with a thermal barrier.

5. Follow steps in *Section 2.2.8* for insulating the collar beam attic.

2.2.8 Insulating Attics with Limited Accessibility

In attics with limited access and no electrical or material hazards are present, insulate with loose fill insulation to a sufficient density to minimize settling. Install dense-packed insulation in inaccessible attic cavities when hidden bypasses have not been addressed by other methods.

These areas may include, but are not limited to:

- ✓ Shed style roof
- ✓ Inaccessible collar-beam attic
- ✓ Inaccessible outer-ceiling-joist attic and knee wall areas

When insulating attics with limited access:

1. Inspect the roof to verify it is in good condition, without visible deterioration.
2. Access the cavity through the gable ends, rafter tails, roof deck, or through the ceiling.
3. Inspect the attic for any air bypasses to the conditioned space. Seal discovered bypasses as directed in *Air Sealing and Indoor Air Quality in Chapter 1 – Section 1.4.*
4. Install blown-in insulation using an appropriate method.

2.2.9 Insulating Closed Roof Cavities

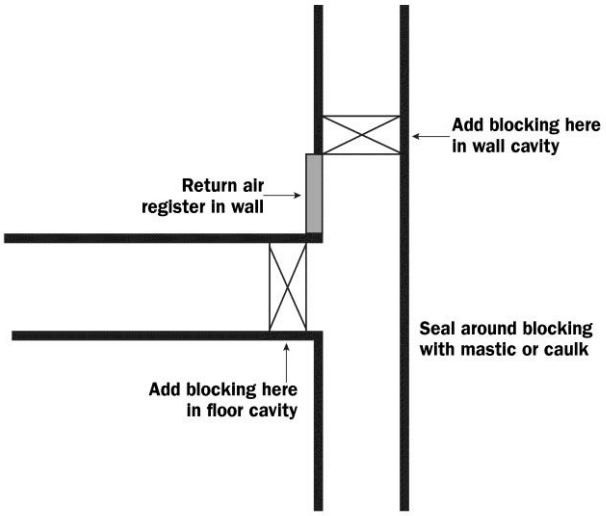
Insulate closed roof cavities with loose fill insulation at a sufficient density to minimize settling, if no electrical or other hazards are present. Install dense-packed insulation in attic cavities when hidden bypasses have not been addressed by other methods.

These areas may include, but are not limited to:

- ✓ Cathedral roof
- ✓ Flat roof
- ✓ Dormers
- ✓ Above bump-outs

When insulating closed roof cavities:

1. Inspect the roof to verify it is in good condition, without visible deterioration.
2. Access the cavity through its gable ends, rafter tails, roof deck, or through the ceiling.
3. Blow the insulation using an appropriate method to ensure proper density of installed insulation.



2.3 Wall Insulation

Properly installed dense-packed wall insulation reduces air leakage through walls and other closed building cavities because the fibers are driven into the cracks by the blowing machine.

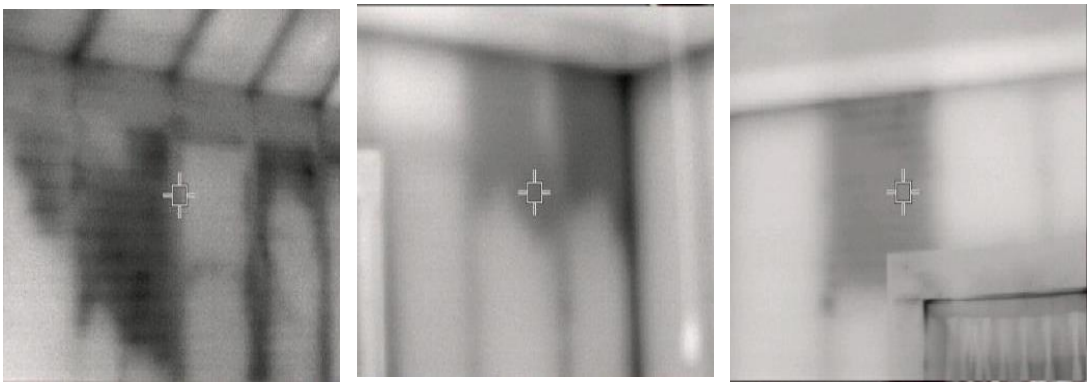
Empty or partially empty wall cavities encourage airflow like chimneys. Convection currents or air leakage can significantly reduce wall insulation's thermal performance if spaces remain for air to flow. Installing dense-packed wall insulation with uniform coverage and density is important. The tube-fill dense-pack method is Wisconsin's chosen wall insulation method because it ensures adequate coverage and density of insulation.

Infrared scanner: Allows the user to see temperature differences, which verify insulation coverage in a wall cavity.

Caution is necessary when tube-filling walls, because the process puts pressure on the interior

and exterior wall surfaces. If the pressure becomes too great on a particular material — such as plaster, drywall, or paneling — the wall could crack or burst. It is also important to check for hidden holes in exterior walls and balloon-framed structures where insulation can escape into basements, attics, closets, and other spaces. Inspect exterior walls to identify cavities that are open to, contain, or are part of the forced-air distribution system. Seal distribution systems in cavities to be insulated. Use extreme care to ensure insulation does not fill wall cavities that are part of the distribution system, which may result in damage to the furnace.

Adequate insulation coverage and density of insulation may be confirmed using an infrared camera and laser thermometer. Whenever possible, use these tools to verify complete insulation coverage. Un-insulated and poorly insulated parts of the wall will display differently than a well-insulated wall. The tool is best used whenever a substantial temperature difference exists, or can be created, on either side of the wall.



Infrared images of exterior surfaces: Dark patches indicate areas with little or no insulation — either insulation voids or framing members.

2.3.1 Calculating Wall Coverage and Density

Dense-packed wall insulation should be installed to a density of 3.5 to 4.5 pounds per cubic foot for cellulose, and 2.0 to 2.5 pounds per cubic foot for fiberglass. These calculations serve to determine the number of bags necessary to insulate walls and to judge density after completing the wall insulation job.

See *Appendix A-3* for the calculation of density and the number of bags needed to achieve the R-value at the settled density.

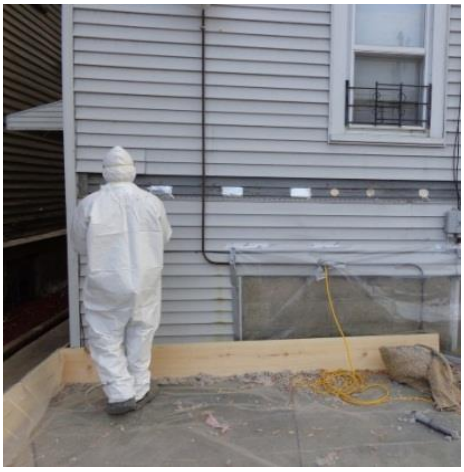
2.3.2 Inspecting and Repairing Walls Before Installing Insulation

1. Inspect walls for evidence of moisture damage.
2. Seal obvious gaps in external window trim or other areas that may permit the penetration of water into the wall.

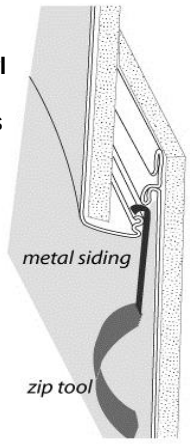
3. Before removing siding, detach any clamps that secure gutters and electrical conduit, etc. to the exterior siding.
4. Inspect indoor surfaces of exterior walls to ensure they are strong enough to withstand the force of dense-packing. Temporarily reinforce or permanently repair weak walls where necessary, prior to dense-packing.
5. Inspect for interior openings from which insulation may escape, such as pocket doors, un-backed cabinets, interior soffits, closets, and balloon-framing openings in the attic or crawl space. Taking a few minutes to investigate these areas will save a lot of time and mess later, if openings do exist. Seal openings as necessary to prevent blown insulation from escaping.
6. Do not insulate cavities used as forced-air distribution. Also, do not insulate cavities containing live knob-and-tube wiring, bare wires, open junctions, or unboxed wire connections. In the customer file, document the location of cavities used as distribution and with live knob-and-tube wiring. See *Electrical Safety in Chapter 5 – Section 5.5*.

2.3.3 Removing Siding and Drilling Sheathing

When insulating a wall from the exterior, remove the outer layer of siding to drill through sheathing and any sub-layers of siding. Removing the siding may make it easier to insert a flexible fill tube, since the tube must pass through one less layer of material. Carefully removed and handled siding is reinstalled after insulating, creating an appearance as close to the original as possible. Drill holes through siding (with building owner's consent) only as a last resort and only if siding cannot be removed. Documentation must be in the customer file detailing the conditions that precluded the removal of the siding.



Some siding materials require specialized procedures. Cement-asbestos board (transite, also called slate siding), and stucco may only be disturbed by persons with appropriate Department of Health Services (DHS) asbestos certification (see the Wisconsin Weatherization Program Manual, Appendix H for complete asbestos policy). Sidewall insulation procedures should follow Lead Safe Weatherization procedures under the direction of a Lead Safe Renovator when applicable (see Wisconsin Weatherization Program Manual, Chapter 9 – Health & Safety, for complete lead policy). Any person who completes this work must be trained in Lead Safe Weatherization procedures.



Removing metal or vinyl siding: A zip tool separates joints in metal siding.

1. Metal or vinyl siding may be removed with a zip tool.
2. Lap siding requires careful prying with a flat bar underneath the nails that fasten the siding to the framing. Cut the paint between pieces of siding with a utility knife before prying.

For more information regarding siding removal, refer to “Dense-Pack Sidewall Insulation” video, available from the Weatherization Training Media Library.

2.3.4 Dense-Packed Wall Insulation from the Exterior

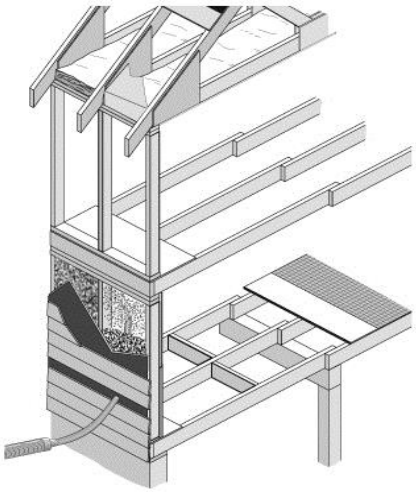
Dense-packed wall insulation is best installed using the tube method with an insulation blower equipped with separate controls for air and material feed. Mark the fill tube in one-foot intervals so the installer knows when the tube has reached the top of the wall cavity and when the end of the tube is almost removed upon completion of dense-packing the cavity.

Insulation hoses, fittings and the fill tube: Gradual reductions in the hose diameter will reduce the chance of plugging the hose with insulation. The goal is to achieve a material to air mixture that maximizes production and correct density.

To prevent settling, loose-fill insulation must be blown at the recommended density of 3.5 to 4.5 pounds per cubic foot for cellulose and 2.0 to 2.5 pounds per cubic foot for fiberglass.

To insulate sidewalls from the exterior:

1. Remove siding, following lead-safe practices if required. See *Lead and Lead-Safe Weatherization in Chapter 5 – Section 5.4.8.* Transite (slate) siding shall be removed intact only by persons with appropriate DHS asbestos certification, unless the siding has been tested and does not contain asbestos.
2. Drill or cut a two- to three-inch diameter hole to access each cavity to be insulated.
3. Probe all wall cavities through holes, to identify fire blocking, diagonal bracing, and other obstacles. After probing, drill or cut whatever additional holes are necessary to ensure complete coverage.
4. Start by insulating several full-height, unobstructed wall cavities with a known quantity



Tube-filling walls: This method can be accomplished from inside or outside the home. It is the preferred wall insulation method because it is a reliable way to achieve a uniform coverage and density.

of insulation so the installed density can be calculated and the blower controls can be set properly.

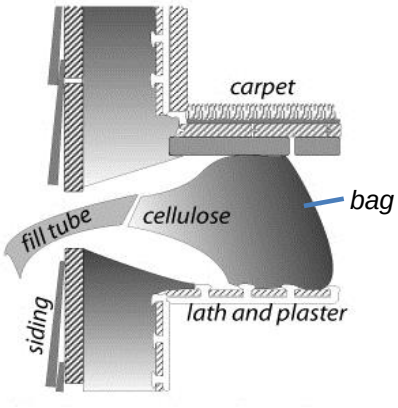
5. Depending on the location of the hole, insert the tube all the way to one end of the cavity Start the machine and back the hose out slowly as the cavity fills. Work the hose back and forth in the cavity to pack the insulation tighter, if necessary.
6. Shut off the flow of material when approximately one foot of tube is remaining in the wall. Re-insert the tube to the opposite end of the cavity, and repeat Step 5. Shut off the flow of material when the cavity is completely full.

Tube-filling walls: Insulation is dense-packed into walls using a fill tube inserted into the wall cavity.

7. Plug the holes, seal the plugs to prevent water and air infiltration, and replace the siding.

When insulating balloon-framed walls or the band-joist areas on multi-story buildings, insulate the perimeter between the two floors by blowing insulation into each floor cavity to create an insulation plug. This technique also prevents air movement through the floor cavity.

If the process is requiring too much insulation, use the ***Bag Method***. See *Method A in Chapter 2 – Section 2.2.7* for information about the ***Bag Method***.



Plugging a balloon-framed floor cavity: Blow a plug of insulation into balloon-framed second floor cavities.

2.3.5 Dense-Packed Wall Insulation from the Interior

In homes where the walls cannot be insulated from the exterior, insulating from the interior may be necessary. Holes drilled for insulation must be returned to an appearance as close to original as possible, or so the result is satisfactory to the customer.

To insulate sidewalls from the interior:

1. Practice lead-safe weatherization techniques. See *Lead and Lead-Safe Weatherization in Chapter 5 – Section 5.4.8*.
2. When testing results require, follow asbestos protocols. See Chapter 9 – Health & Safety of the Wisconsin Weatherization Program Manual for comprehensive asbestos policies.
3. Drill holes and stagger them by at least six-inches up and down, which will reduce horizontal cracking in lath-and-plaster walls.
4. Use a non-conductive probe to determine where to drill into the next cavity.

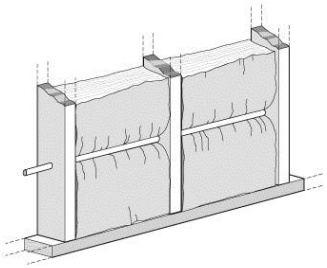
5. Insert a fill tube, and dense-pack the cavity following the procedures detailed in *Dense-Packed Wall Insulation from the Exterior in Chapter 2 - Section 2.3.4.*
6. Use wooden plugs along with joint compound or quick-setting plaster to seal and patch the holes.
7. Chair rail or wallpaper trim can be installed to conceal the holes if necessary.
8. Remove the baseboard or chair rail when possible to allow drilling. Use wood plugs and joint compound or quick-setting plaster to seal the holes before re-installing the baseboard or chair rail.

2.3.6 Dense-Packing from Other Access Locations

Balloon-framed cavities can often be insulated from either the attic or basement where the cavity is open. In these cases, use a temporary dam to completely fill the cavity with dense-packed insulation, following the procedures described in *Installing Attic Insulation in 1½-Story Homes (Finished Attics) in Chapter 2 – Section 2.2.7.*

2.3.7 Interior Open-Cavity Wall Insulation

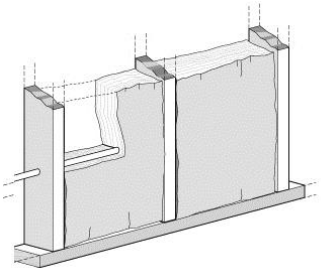
Fiberglass batts achieve their rated R-value only when installed correctly. If gaps exist between the cavity and batt at the top and bottom, or if the batt is compressed, the effective R-value can decrease by as much as 30 percent.



Fiberglass batts, compressed by a cable: This reduces the wall's R-value by creating a void between the insulation and interior wallboard.

To insulate open interior-wall cavities:

1. Prior to installing insulation, air-seal the exterior wall sheathing.
2. Use appropriately sized, un-faced friction-fit fiberglass batt insulation where possible.
3. Choose high-density batts whenever possible, and install to the maximum structurally allowable.
4. Install the batt to fill the entire cavity, without spaces at the corners or edges.
5. Cut batt insulation to the exact height of the cavity. A short batt creates air spaces above and beneath the batt, allowing convection. A long batt bunches up, creating air pockets.
6. Split batts around wiring, rather than letting the wiring bunch the batt to one side of the cavity.
7. Insulate behind and around obstacles with scrap pieces of batt.



Batt, split around a cable: The batt attains its rated R-value.

8. Prior to installing drywall, cover exposed un-faced insulation with an airtight polyethylene vapor retarder. Install the vapor retarder to the warm side of the wall.
9. Kraft- or foil-faced insulation exposed to the interior living space must be covered with minimum half-inch drywall or other material having an ASTM E84 flame spread rating of 25 or less. (Exception: Insulation with a Class A Facing with a flame spread of 25 or less.)

Dense-packed insulation may sometimes be blown into open stud cavities through an air barrier or plastic mesh. This is a good option if the insulation is packed densely enough to resist settling. The mesh will bulge if installed at the proper density; however, it could hinder drywall installation. Instead, consider cutting holes in the drywall to tube-fill the cavities with dense-packed insulation after installing drywall.

2.4 Crawl Space Requirements

Crawl spaces are usually small and difficult areas to complete work. Agencies should have a written policy for the minimum working requirements to effectively complete the necessary work in a crawl space.

2.4.1 Crawl Space Access Requirements

When creating new access to a crawl space, the following access sizing guide should be implemented:

Access Type	Size
Floor access	18" x 24"
Perimeter wall access	16" x 24"

A new access may need to be smaller if the existing framing members constrain work. Do not disturb framing or structural systems to install the access hatch.

2.4.2 Crawl Space Signage

A laminated sign, at least 8½" x 11" in size, should be posted at every access, inside of the crawl space. The sign will include the following information:

- ✓ Contact information for the installer.
- ✓ List of mechanical components installed in the crawl space.
- ✓ Statement prohibiting the storage of hazardous and flammable materials.
- ✓ Caution statement for those entering the crawlspace not to damage the air barrier, ground moisture barrier, and/or insulation.
- ✓ Installer contact information will be included on the sign in case there are questions or need for repairs.

2.5 Floor and Foundation Insulation

Insulation and air sealing of the foundation combine to complete the thermal boundary at the base of the building. As parts of the foundation are identified and defined as inside of the thermal and pressure boundaries, it is very important to ensure exposed soil is covered with a ground moisture barrier. Assess the crawl space ground area for health and safety issues and debris that could potentially damage the ground moisture barrier. Properly dispose of any identified items. Install a ground moisture barrier in accordance with 2012 *IRC* N1102.2.4 and 2012 *IRC* AF103.4.10 (minimum 6 mil in thickness) over exposed earth. Install a thicker ground moisture barrier if items are present in the crawl space that could reduce the effectiveness and durability of the barrier. Overlap the seams of the ground moisture barrier a minimum of 12 inches with “reverse” or “upslope lapping” technique (e.g., overlapping so water will not flow in between the seams). Install the wall vapor retarder under the ground moisture barrier at the wall to floor connection. The air barrier and ground moisture barrier should not interfere with the established drainage pattern. Interior drainage collection points will remain accessible.

Ensure the ground moisture barrier is not damaged when installed or when performing work. Seal with the appropriate materials if it is damaged in the work process.

If an existing drain is present, the installed ground moisture barrier should not prevent flow of moisture to the drain.

The choice between insulating the floor or the foundation should be made based on accessibility and if heating distribution or plumbing runs through the area. Basements are generally not insulated during weatherization, but sealing is typically required to stop air infiltration. For other considerations, see *Locating the Pressure/Thermal Boundary in Chapter 1 – Section 1.5.3*.

2.5.1 Establishing a Thermal Boundary

To establish an effective thermal boundary, the insulation and air barrier should be adjacent to each other, with the air barrier located between the insulation and the conditioned space.

In most Northern climates, the preferred method is to insulate and air seal the foundation walls and not the floor. This includes sealing crawl space vents. This strategy encloses the furnace, ducts, pipes, and other features within the thermal and pressure boundaries.

Insulating and air sealing rim joist: Rigid board insulation installed in joist cavities, with spray foam to seal at the edges.

2.5.2 Rim Joist and Sill-Box Insulation

The joist spaces at the perimeter of the floor can be a weak point in the thermal boundary. Insulating both the rim joist and longitudinal box joist are appropriate either as individual procedures or as part of floor or foundation insulation.

Air seal stud cavities in balloon-framed homes as a part of insulating the rim joist. If the sill box will be insulated, two-part foam can be useful as it insulates and air-seals in one application. One primary advantage of two-part foam is its ease of installation in areas of limited accessibility. Follow the foam manufacturer's installation instructions and applicable building codes when installing two-part foam. Before applying spray foam, ensure the substrate is dry and reasonably clean. Do not apply more than 3 inches of spray foam in the sill-box area.

Use appropriate personal protective equipment (PPE) when installing two-part foam. Follow the manufacturer recommendations for safety precautions. See *Personal Protective Equipment in Chapter 5 – Section 5.1 and the General Information on Spray Polyurethane Foam (SPF) Appendix A-4* for additional information.

Rigid board insulation is also good for insulating and air sealing the rim-joist area. If foam board is used to insulate the rim, spray foam can be used to seal around the edges. Longitudinal box-joist cavities, enclosed by a floor joist, may be sealed and blown with wall insulation unless there is evidence of a moisture problem in the area. If the insulation will be in direct contact with the foundation, cellulose insulation should not be used to prevent potential moisture issues.

Use faced fiberglass batt insulation with caution. Air can circulate around the fiberglass, causing condensation and encouraging mold on the cold rim joist. Fiberglass batts may be used to insulate the rim joist only when:

1. The sill box is effectively air-sealed.
2. The batts are cut to the proper size and completely fill the cavity.

2.5.3 Floor Insulation

Prior to insulating the floor, take all appropriate measures to establish an effective air barrier at the floor, in order to prevent air from passing through or around floor insulation.

Insulating Open Floor Cavities

Install a ground-moisture barrier that runs up the foundation walls at least six inches in crawl spaces. Seal the ground-moisture barrier to the foundation wall with appropriate material, and seal all seams and penetrations as well.

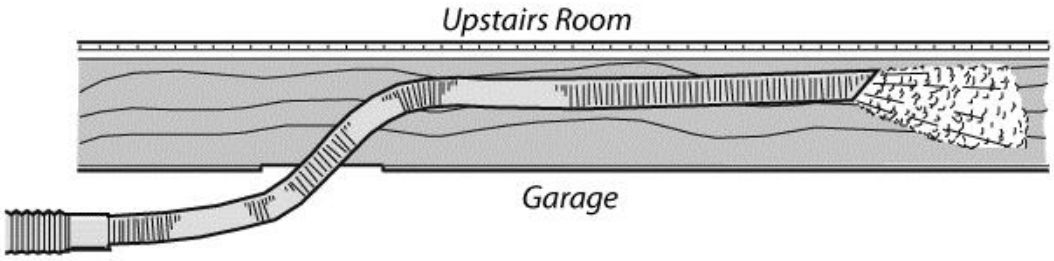
Caution: Moisture barriers are typically for use in crawl spaces. In basements, restrict their use to basements with dirt floors and limited access. If the ground-moisture barrier is installed in a seldom-used basement, install walk boards to prevent residents from slipping. Problems such as plumbing leaks or bad site drainage must be addressed prior to installing the barrier, to avoid water pooling on or under the barrier.

Complete the following when insulating open floor cavities:

1. If the walls are balloon-framed, contain wall insulation by air sealing the bottoms of the stud cavities prior to installing floor insulation.
2. Install the maximum thickness of insulation between floor joists that the structure allows. Fill the entire joist space if possible. Fit floor insulation tightly against the subfloor and the rim joist to reduce air convection.
3. Install insulation without voids, edge gaps, or end gaps. Fit insulation closely around cross bracing and other obstructions.
4. Securely support batt insulation within each cavity with insulation hangers, plastic mesh, a vapor-permeable air barrier, or other supporting material.
5. Seal and insulate ducts remaining in the crawl space or unoccupied basement. See *Forced-Air Furnace Air Distribution in Chapter 3 – Section 3.4* for information on sealing and insulating ductwork.
6. Consider installing a vapor-permeable air barrier to prevent convective looping, support the insulation, and keep pests out.

Insulating Enclosed Floor Cavities

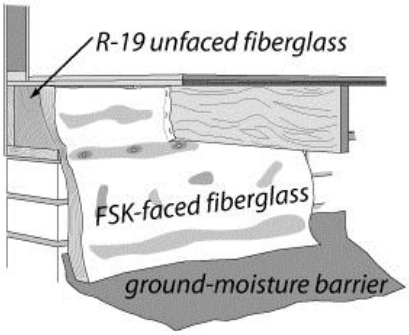
Install dense-pack insulation in floor cavities. Confirm the cavities are enclosed by rigid sheeting. This method works well in garage ceilings, cantilevered floors, and beneath bay windows.



Blowing a garage floor cavity: Uninsulated floor cavities can be insulated with blown fiberglass or cellulose insulation, using a fill tube.

2.5.4 Foundation Insulation

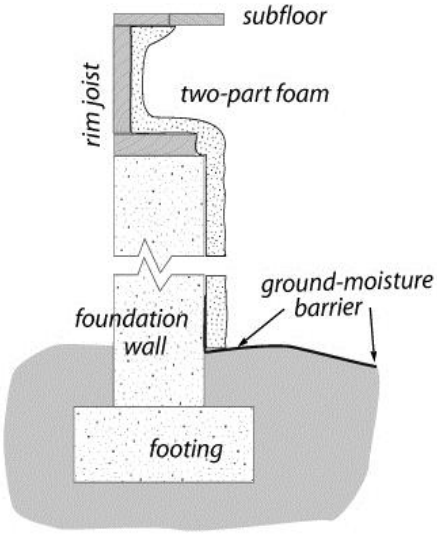
Foundation insulation is usually installed on the inside of the foundation wall. Less frequently, foundation insulation is applied from the home's exterior. Where termite pressure may exist, removable band joist insulation will be installed.



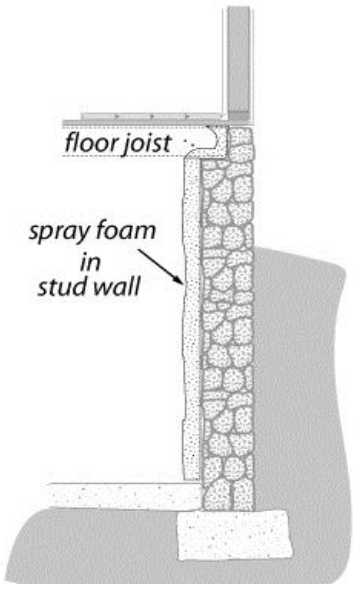
Fiberglass foundation insulation: Use this method only in dry conditions where the drainage outdoors is effective.

Interior Foundation Insulation

1. Attach insulation to the inside wall surface with appropriate fasteners and/or adhesive. Install insulation with no significant voids or edge gaps.
2. Foil Scrim Kraft (FSK) fiberglass insulation should be attached to the sill plate, floor joists, and/or floor. Insulate the rim joists with un-faced fiberglass before installing the FSK-faced insulation to prevent a void behind the FSK insulation at the rim joist.
3. Securely attach extruded or expanded polystyrene or foil-faced polyisocyanurate insulation boards when installed on flat foundation walls.



Two-part foam sprayed on rubble masonry: Rubble masonry walls can be insulated on the interior with sprayed foam.



Foam-insulated crawl space: Two-part foam insulates and seals the rim joist as well as insulating the foundation walls.

4. Spray two-part foam on the interior surface of the foundation to maintain the required insulation level. This may require application of more than one coat to assure full curing of the material. Take proper precautions for the safety of the crews and occupants during installation. Follow the manufacturer's recommendations for application and for safety equipment to be used. Follow all applicable building codes. When applied

correctly, two-part foam will insulate and air seal the foundation. Typically, two-part foam expands to twice the thickness of the initial application, so be careful not to over-insulate. See the *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.

5. In cold weather, apply a skim-coat of foam first, before fully spraying the wall. The skim-coat will heat up the wall, which will help the foam adhere to the wall.
6. When two-part foam is used, a thermal barrier is required to separate the foam plastic from the living area. Thermal barriers can be applied to a wall that separates crawl space insulation from a basement. For buildings with only a crawl space, the plywood flooring serves as the separation.
7. Attach outside access hatches securely to the foundation wall, latched and weather-stripped. The hatch should be lockable. Insulate the hatch only when it is part of the thermal boundary.

Exterior Foundation Insulation

1. Install exterior foam insulation to a minimum depth of six-inches below grade, unless restricted by non- excavatable ground, such as a sidewalk. Apply a durable covering or coating to the entire surface of the insulation, including joints and corners.
2. Completely cover the exposed foundation with insulation.
3. All connecting joints must form a seal or be sealed with appropriate sealant.
4. If the insulation is not protected by the siding, install a drip edge.

Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

Attic Insulation

Attic Insulation Storage Area

1. The storage area is as small as possible and still meets the homeowner's needs.
2. Floor plugs installed if needed.
3. The insulation installed beneath the storage area is a minimum of R-19.
4. The storage area presents no hazards to occupant.
5. Items in the storage area were protected from insulation.
6. Floor boards were re-installed properly.

Damming and Boxing

1. The dam is the same height or higher than the surrounding insulation.
2. The dam is effective in performing its specified function.
3. When necessary, the dam is constructed of non-combustible material.
4. The chimney dam is at least two inches from an active chimney or per manufacturer's instructions.

Attic Access

1. Allows for repeated access to attic.
2. All trim is properly sealed and weather-stripped.
3. Access panel is insulated to same R-value as the attic or the maximum structurally allowable, whichever is lower.
4. Access is covered with an appropriate fire rated material, such as $^{5}/_{8}$" drywall (as required by code).

Attic Bypass Sealing

1. Bypasses are sealed to the level called for under Wisconsin's Weatherization Program requirements.
2. Bypasses are sealed with an appropriate material and amount of material.
3. All equipment mounted in the ceiling is properly air sealed.

Roof Leaks

1. No visible evidence of roof leaking is present.

Attic Wiring

1. All electrical boxes are covered, sealed, and flagged if concealed by insulation.
2. All live knob-and-tube wiring is boxed out prior to insulation, the boxing ends are sealed, and the boxing is flagged.
3. Rewired (permit pulled, if applicable) and inspected (if required).

Heat Producing Products (lights, chimneys, flues, attic furnaces)

1. Boxing is a minimum of three inches from device. Boxing material is gypsum wallboard, cement board, or other code-approved material.
2. Active chimneys meet all chimney guidelines (e.g., no cracking, no creosote present, structurally sound, etc.)

Exhaust Fans and Vent Stacks

1. Vents will exhaust the specified area to the outdoors.
2. Stacks are properly sealed at intersection with building materials.

Attic Vapor Retarders

1. Installed correctly toward the warm side.
2. Installed in continuous manner, with edges sealed.

Attic Venting

1. Allows air to pass through vent.
2. Installed vents are higher than the insulation material.
3. Vents are made of corrosion-resistant material appropriate for their specific location.
4. Vents have screens with non-corroding wire mesh with openings of $^{1}/_{16}$" to ¼" to prevent pest entry (e.g., birds, bats, and bees).

Attic Floor Insulation, Open Blow

1. Installed to the R-value selected by the audit.
2. Insulation is installed to a uniform R-value, with no variances of greater than two inches.
3. All wiring is properly flagged, no bare wiring.
4. Live knob-and-tube wiring is properly dammed and sealed.

5. Insulation certificate is properly posted.

Attic Cavities (site built)

1. All areas specified are insulated.

Knee Wall Attic Walls

1. All cavities are filled to the maximum amount.
2. The permeable air barrier has seams and edges, are sealed, and it is mechanically fastened.

Sidewall Insulation (site built)

1. All cavities are properly insulated to the maximum allowable amount and proper density.
2. Blown insulation is installed from the exterior or the attic unless limited by the building structure or health and safety issues, with prior approval of the building owner.
3. Based on file documentation (photos), work has been completed in a lead safe manner.
4. All siding that is suspect ACM has been addressed under the supervision of a competent person.

Sidewall Wiring

1. All hazards are addressed prior to insulating.

Floors Over Unheated Areas (site built including cantilevers)

1. Insulated to the maximum structurally allowable.
2. Permeable air barriers may be used on the cold side of the insulation.
3. Weather and pest-proof cover between cantilever insulation and the outside.

Sill Box Insulation

1. Area is sealed and filled to the R-value selected by the audit.

Interior Foundation Insulation

1. Area is insulated to the R-value selected by the audit.
2. If two-part foam is installed, there must be a barrier between the area of application and living area of the building, including unintentionally heated basements.
3. Continuous ground moisture barrier covers all exposed soil surfaces and is sealed to the wall.

Exterior Foundation Insulation

1. A minimum of R-5 insulation installed.
2. NEAT documentation in the file.
3. Depth of the insulation is at least six inches and not greater than 14 inches.
4. Material has protective coating at least six-inches below grade.
5. An effective drip edge makes a positive seal between the foundation and the wall assembly.