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Insulation Basics

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Insulation is any material that reduces the rate of heat transfer from one area to another. In the winter, insulation reduces the heat loss from a residence, decreases the amount of supplemental heat required, and prevents condensation or "sweating" of water vapor by increasing the inside surface temperature. During the summer, insulation reduces heat gain and provides a cooler environment. Adding a vapor retarder on the warm side of the wall reduces the movement of water vapor from the inside air through the exterior building materials.

Any product with a relatively high resistance to heat flow can be considered an insulator. The R-value (or thermal resistance) of a material is a measure of its ability to resist heat loss/heat gain. Insulation values vary from R-7 per inch for polyisocyanurates to relatively no R-value for steel. An insulation of R-7 provides seven times more resistance than a material of R-1. The R-values of common building materials are given in Table 1; a more complete list appears in the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) *Handbook of Fundamentals.*

Insulation Materials

Fiberglass and **mineral wool,** including rock and slag wool, are made with a fibrous form process using rock, slag, or glass. Fiberglass differs from rock wool only in the source from which the fibers are spun. The materials are noncombustible, noncorrosive, and odor-free.

Cellulose, which is made from paper or pulp products, must be chemically treated with a fire retardant.

Vermiculite, a mica, is used as a loose fill attic insulation and as an insulator within concrete block and hollow wall construction.

The group of foams known as cellular plastics includes **expanded polystyrene, extruded** or **molded polystyrene, polyurethane,** and **polyisocyanurates.** Expanded polystyrene that is used for foundation insulation, exterior sheathing, and sidings should not be exposed to sunlight or moisture over a long period of time. Extruded polystyrene, which is manufactured as Diversifoam, Certifoam, Dow Styrofoam, and similar products, is used for many roofing, foundation, and subsoil applications. Polyisocyanurates are used on exterior walls and for roofing systems. Polyurethane is a foam that is blown into wall cavities. These materials require fire-resistant treatment or a fire-resistant barrier to reduce the rate at which air can reach them if they should ignite.

Forms of Insulation

Four common forms of insulation are batt and blanket, loose fill, rigid, and foam. Some insulating materials are manufactured in more than one form. Selecting which insulation form and material to use depends on the specific application and the cost.

Batts and **blankets,** which are made from fiberglass or mineral wool, are the most common forms of insulation. They are designed to fit within conventional framing and are available in a variety of thicknesses. Although they are available with a vapor retarder attached to one side, some of the retarders used may be inadequate for Minnesota conditions. Buying an insulation without a vapor retarder and then installing a separate vapor retarder of the correct rating will provide adequate insulation. Batts are usually cut in 8-foot lengths, whereas blankets come in continuous rolls. Batts and blankets are used throughout a residence for walls, ceilings, and crawl spaces.

Loose fill, which is blown in or poured, is made from a variety of materials, including mineral wool, cellulose, fiberglass, vermiculite, and polystyrene. Available in bags, the material is either poured into a space or blown in with special equipment that can be rented. Loose fill is most commonly used in ceilings and can be the most

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Table 1. R-values of common building materials.*

Material	R-value: Per inch (approximate)	R-value: For thickness listed
Batt and blanket insulation		
Glass or mineral wool, fiberglass	3.00-3.80†	
Loose fill		
Cellulose	3.13-3.70	
Glass or mineral wool	2.50-3.00	
Vermiculite	2.20	
Rigid insulation		
Expanded polystyrene		
Extruded, plain	5.00	
Molded beads, 1 pound/cubic foot	5.00	
Molded beads, over 1 pound/cubic foot	4.20	
Expanded rubber	4.55	
Expanded polyurethane, aged	6.25	
Glass fiber	4.00	
Wood or cane fiberboard	2.50	
Polyisocyanurate	7.04	
Foamed-in-place insulation		
Polyurethane	6.00	
Building materials		
Concrete, solid	0.08	
Concrete block, three hole, 8 inch		1.11
Lightweight aggregate, 8 inch		2.00
Lightweight, cores insulated		5.03
Brick, common	0.20	
Metal siding	0.00	
Hollow-backed		0.61
Insulated-backed, ⅜ inch		1.82
Softwoods, fir and pine	1.25	
Hardwoods, maple and oak	0.91	
Plywood, ⅜ inch	1.25	0.47
Plywood, ½ inch	1.25	0.62
Building materials (continued)		
Particleboard, medium density	1.06	
Hardboard, tempered, ¼ inch	1.00	0.25
Insulating sheathing, 25/32 inch		2.06
Gypsum or plasterboard, ½ inch		0.45
Wood siding, lapped, ½ x 8 inch		0.81
Asphalt shingles		0.44
Wood shingles		0.94
Windows (includes air films)		
Single glazed		0.91
with storm windows		2.00
Insulating glass, ¼ inch air space		
Double pane		2.85
Triple pane		3.70
Doors (exterior, includes air films)		
Wood, solid core, 1¾ inch		3.03
Metal, urethane core, 1¾ inch		2.50
Metal, polystyrene core, 1¾ inch		2.13
Air space (¾ to 4 inches)		0.90
Air films		
Inside surface		0.68
Outside surface		0.17
Floor perimeter (per foot of exterior wall length)		
Concrete		1.23
Concrete, with 2x24 inch or rigid insulation around perimeter		2.22

* Values are from either the 1985 ASHRAE *Handbook of Fundamentals* or from Midwest Plan Service AED-13, *Insulation and Heat Loss.*

† The R-value of fiberglass varies with batt thickness and manufacturer; check the label.

economical form of insulation for a given R-value. It is also popular for insulating irregularly shaped areas.

Insulating an existing wall with loose fill requires expertise to prevent settling, which leaves the top portion of the wall inadequately insulated. Select a material, such as cellulose, that will not snag on obstructions in the wall (nails, etc.). Settling or packing of loose fill after installation will reduce its overall R-value, but its R-value per inch may slightly increase.

Rigid insulation boards are made from fiberglass, cellulose, fiberboard, or cellular plastics. Selecting this form of insulation is sometimes based on the need for rigidity and strength. Although rigid boards made from a plastic foam have a high R-value per inch, they may be more expensive than loose fill, batt, or blanket for a given R-value.

Foam insulation, which includes polystyrene and polyurethane, can be installed directly under metal roofing or as an interior liner for a building. Because of the potential for chemical reactions, polyurethane should be sprayed into a wall/roof by a professional. In 1982, the Consumer Product Safety Commission banned the use of urea formaldehyde in new residences. All foam should be considered flammable, and all foam may release toxic gases when burned.

R-Value Calculations

Heat loss is the amount of heat lost through a building section or the building as a whole due to the insulation level and the inside and outside temperatures.

Heat loss can be calculated as follows:

$$\text{Heat loss} = \frac{\text{Area}}{\text{R-value}} \times \left(\text{Temp inside} - \text{Temp outside}\right)$$

Where: Heat loss = Btu/hr
Area = square feet
R-value = hr ft^2 °F/Btu
Temperature = °F

The total R-value, or insulation level, of a section is calculated by adding the R-values of the individual materials (Figure 1). The air film coefficient is the resistance to heat flow between the surface and the air.

The average R-value for the total wall (insulated section, frame section, windows, etc.) is found by first dividing the area of each section by its R-value. The values are then added together and divided into the total area, as shown in Table 2.

Table 2. Example calculations for average R-value of a wall.

Area type	Area (ft^2)	R-value (hr ft^2 °F/Btu)	Heat loss (Btu/hr °F)
Insulated	800	22.43	800/22.43 = 35.7
Frame	200	10.30	200/10.30 = 19.4
Window	50	2.5	50/2.5 = 20.0
Total	1,050	-	75.1

Average R-value of the wall $= \frac{1{,}050}{75.1} = 14.0$

$$\text{Heat loss per °F for total wall} = \frac{\text{Area}}{\text{R-value (insulated section)}} + \frac{\text{Area}}{\text{R-value (frame section)}} + \frac{\text{Area}}{\text{R-value (window section)}} + \text{etc.}$$

$$\text{Average R-value for total wall} = \frac{\text{Total area}}{\text{Total heat loss per °F}}$$

Another common term, the U-value (overall thermal transmittance), describes the rate at which heat will pass through a material. The U-value is equal to 1 divided by the R-value.

$$\text{U-value} = \frac{1}{\text{R-value}} \text{ Btu/hr ft}^2 \text{ °F}$$

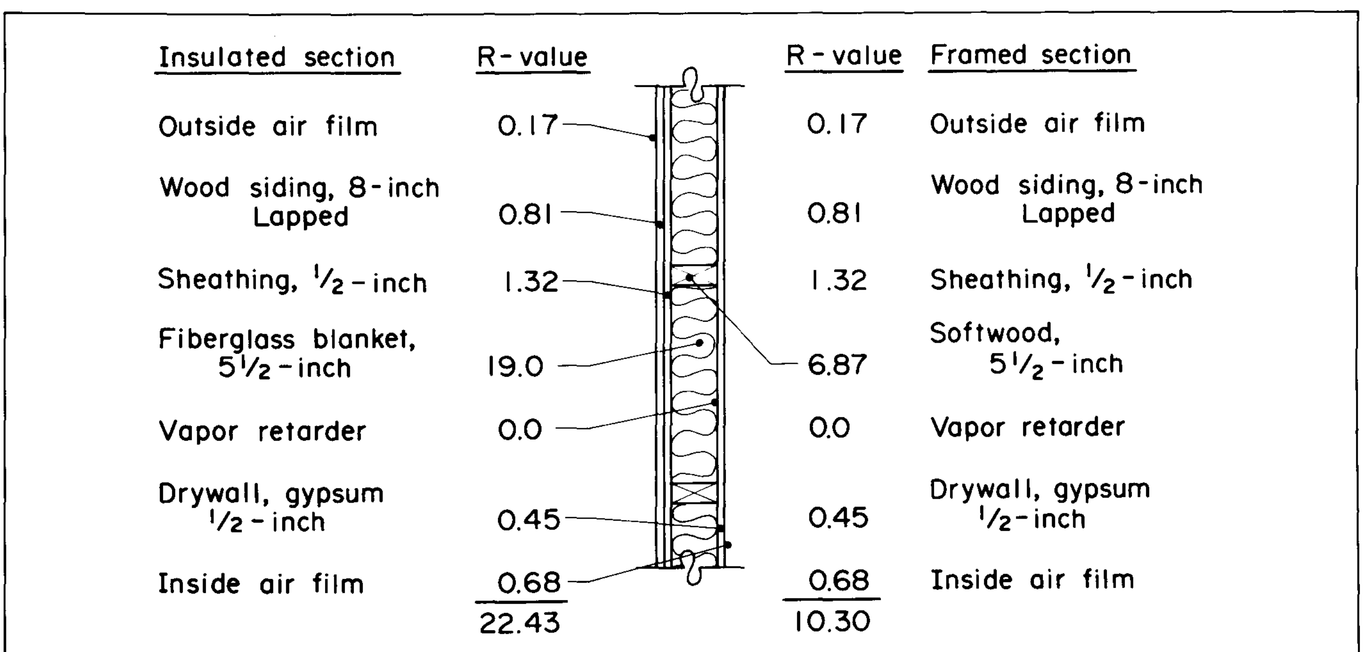

Figure 1. Detailed R-values for the insulated and framed sections of a typical 2x6 wall cavity.

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Heat loss below ground level requires a more complicated R-value calculation than shown because of the insulating value of the ground. Refer to the ASHRAE *Handbook of Fundamentals* for more information.

Vapor Retarders

Vapor retarders are useful for reducing the amount of water vapor that can move from the inside air through the building materials to the outside air. Because warm air can hold more moisture than cold air, inside water vapor pressure (where the air is warm) can force the vapor to the colder outside air. The air within the building materials can then become saturated and the vapor will condense when cooled to the dewpoint.

A vapor retarder is a product that substantially resists the flow of vapor. The term *vapor retarder* has replaced the term *vapor barrier* because the material only reduces moisture transfer. The term *perms* refers to the ability of a material to allow vapor to move through it. A material with a low perm rating does not allow water vapor to pass through as readily as a material with a high perm rating. The Minnesota Energy Code requires that vapor retarders have a perm rating of 0.1 or less for building construction. Polyethylene is a commonly used vapor retarder.

The dewpoint of the air is the temperature at which it will become saturated. Vapor will condense from the air if it comes in contact with a material at or below the dewpoint temperature. Figure 2 shows how the temperature would vary at different positions in the wall described in Figure 1. In this example, the dew-point temperature (40° F.) is found in the middle of the insulation and approximately the middle of the wood stud. Any vapor present at these and colder locations would condense, creating moisture that would cause building material decay.

Condensation within a building section will lower the R-value of the insulation, promote decay of the structural members, and cause paint problems on the walls. Reduced R-values will further decrease temperatures and accelerate the condensation of moisture.

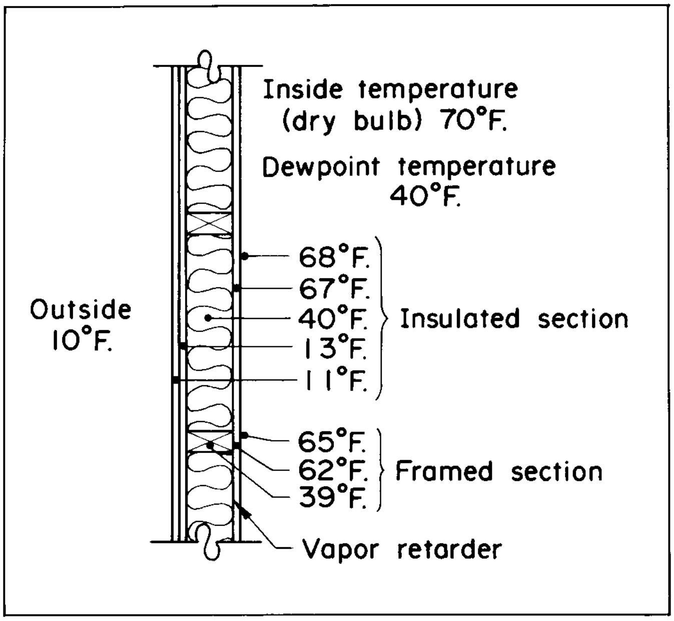

Figure 2. Temperature variations within an insulated wall cavity.

A vapor retarder is needed on the inside before the material reaches its dewpoint temperature. To create a well-insulated residence, the vapor retarder should be placed as near the inside as possible and always within the first one-third of the R-value on the heated side of the wall. A vapor retarder can also serve as an air barrier, reducing drafts and heat loss due to infiltration.

For additional information, contact your local county extension office and ask for the publication *Insulation, R-value, and Fuel Savings* (HE-FO-1857).

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