CD-FO-3399—1988
Minnesota Extension Service

COLD CLIMATE HOUSING INFORMATION CENTER
UNIVERSITY OF MINNESOTA

Residential Heat Loss

Fred C. Vosper and
Barbara J. Wiersma

Most heat loss in a residence occurs through either transmission or infiltration. Transmission is the transfer of heat energy by conduction and convection through the exterior structure. (Conduction is heat transfer through a solid material, whereas convection is heat transfer between a surface and air.) Infiltration is the exchange of inside air with outside air. All homes have this exchange of air. Any cold air entering the home must be heated and constitutes a significant load on the heating system.

Heat loss from a residence can be analyzed by evaluating the building envelope. The major areas for heat loss are the roof/ceiling, walls, windows, doors, exposed floors, and foundation/basement (Figure 1). Factors for determining the amount of insulation needed include the type of construction, inside and outside temperatures, the amount of exposed area, and the cost of installation. State codes may dictate some requirements or limitations.

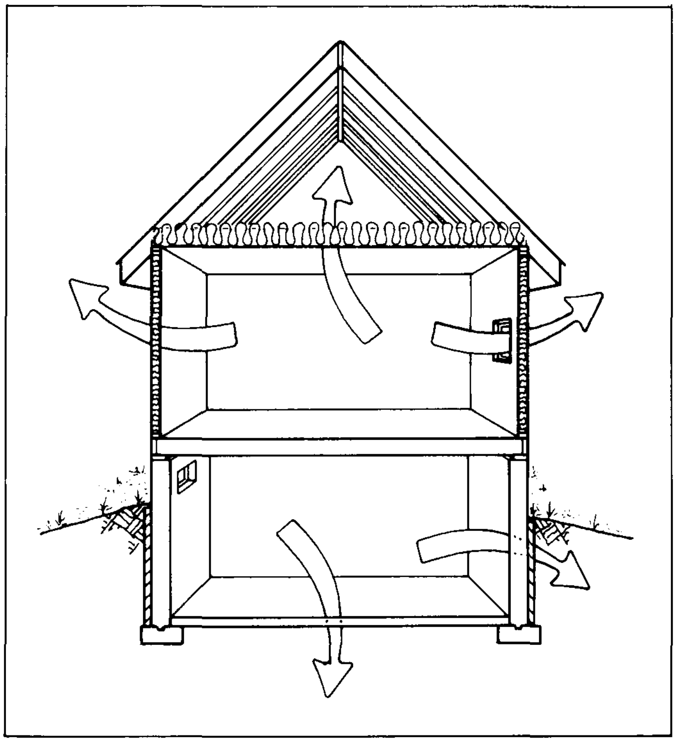


Figure 1. Major areas of heat loss. The relative amount of heat loss from any point in the building envelope depends on R-value, infiltration, temperature differences, etc.

Determining Heat Loss

Transmission

Heat loss by transmission can be calculated as follows:

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

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

An indication of the major heat loss areas can be seen by determining the heat loss from each type of section (walls, windows, etc.). This is done by taking the area of each section and dividing that by the average R-value of the section, as shown in Table 1. (The R-value — or thermal resistance — of a material is a measure of its ability to resist heat loss/heat gain.) In this example the walls and windows account for two-thirds of the heat loss by transmission. Foundation walls and floors are not included in this comparison because soil temperatures can be different from outside air temperatures.

The Cold Climate Housing Information Center is a part of the Minnesota Cold Climate Building Research Center, and is administered through the Minnesota Extension Service.

Table 1. Example of comparison of sources of residential heat loss by transmission.

Section	Area (ft^2)	R-value (hr ft^2 °F/Btu)	Heat loss per °F (Btu/hr°F)	Percentage of total
Ceilings	1,200	38	1,200/38 = 31.6	16
Walls	1,600	20	1,600/20 = 80.0	40
Windows	140	3	140/3 = 46.7	23
Doors	40	3	40/3 = 13.3	6
Glass doors	40	3	40/3 = 13.3	6
Foundation above grade	95	5	95/5 = 19.0	9
Total	3,115	-	203.9	100

Insulation Balance

It is important to compare the heat loss through each section of your structure to determine the most effective use of your insulation dollar. A balance of insulation between the various sections of the residence provides good insulating qualities for the wall as a whole.

For example, a 200-square-foot wall of R-12 that has a 15-square-foot window of R-1 would lose about the same amount of heat by transmission through the window as through the rest of the wall — a total of about 30 Btu/hr°F. You could insulate the wall to R-30 or improve the window to R-3 to get about the same reduction in heat loss. If you improved both the wall and the window, you would reduce the heat loss to about one-third of the unimproved condition.

Establishing a balance among the areas of heat loss is one way of evaluating insulation alternatives. Table 2 provides different insulation levels for balanced residences. The level of insulation that is best for your residence depends on many factors, including the type of construction and the fuel source. When making improvements, it is important to consider low-cost methods first. The Minnesota Energy Code sets minimum standards for new construction, remodeling, and additions to residences (information is available through the Minnesota Energy Information Center, 900 American Center Building, 150 East Kellogg Boulevard, St. Paul, MN 55101; 612-296-5175).

Infiltration

Infiltration can account for a substantial portion of the total heat loss in a residence. Losses occur through open doors and windows, cracks around doors and windows, construction joints, holes for electrical fixtures and wires, and building materials. An air barrier placed within the wall section and properly sealed around doors, windows, and holes for electrical fixtures and plumbing is used to reduce infiltration. Reducing the infiltration openings often provides the homeowner with a more draft-free house.

The amount of energy spent to heat incoming air due to infiltration depends on the amount of air leakage and on the temperature difference between the indoor and outdoor air.

Heat loss from infiltration can be calculated as follows:

$$\text{Heat loss} = 0.018 \times \text{Volume of the home} \times \text{Air changes} \times \left(\text{Temp inside} - \text{Temp outside}\right)$$

Where: Heat loss = Btu/hr
Volume of the home = cubic feet
Temperature = °F
Air changes = number per hour

Table 2. Relative levels of insulation.

Level	Average R-value (hr ft^2 °F/Btu) Ceilings	Walls	Windows	Doors	Foundation	Infiltration (air changes per hour)
Standard	19	11	2	3	4	1-2
Well-insulated	50-55	24-30	3	8	10-15	0.3-0.5
Super-insulated	70-80	40-50	4-6	16	15-35	0.05-0.25
Minnesota Energy Code	38	20	3	3	5 entire (top to footing) or 10 to frostline	

One air change is equal to the volume of the residence. Typical rates vary from 0.2 to 2.0 air changes per hour, with 0.5 or less air change per hour for new construction. If the example building in Table 1 had a volume of 14,400 cubic feet and 0.5 air change per hour, the heat loss by infiltration would be:

Heat loss = 0.018 x 14,440 x 0.5 x Temperature difference
= 129.6 x Temperature difference

The total heat loss above ground level due to transmission and infiltration for the residence would be:

Total heat loss = (Transmission + Infiltration) x Temperature difference
= (203.9 + 129.6) x Temperature difference
= 333.5 x Temperature difference

Therefore, the heat loss by infiltration would be approximately one-third of the total.

Low-cost energy savings can be made by reducing infiltration. All openings or breaks in the air barrier, including outlets and switches, should be sealed. Exhaust fans in the kitchen and bathrooms and dampers for the clothes dryer and fireplace can be sources of infiltration. Air leakage can occur around a fireplace and up through the flue. An energy efficient fireplace or furnace uses outside air for combustion and should be sealed with a glass enclosure to prevent inside air from entering the flue.

Although infiltration should be minimized to reduce heat loss, adequate air exchanges are still required for safely removing pollutants and moisture. For more information, see the publications *Home Energy Conservation* and *Combustion Air for Safe Heating and Moisture,* which are available from the Minnesota Energy Information Center.

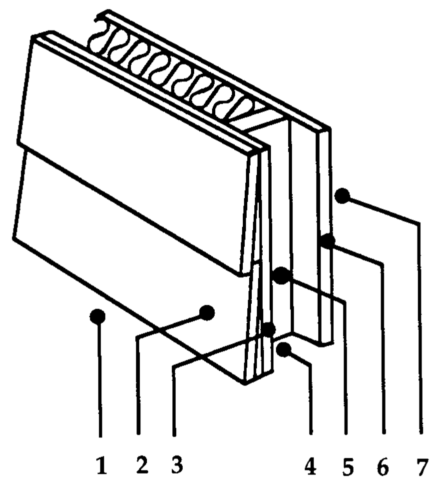


Figure 2. A 2x4 wall cavity.

Controlling Heat Loss

Ceilings

Insulation and a tightly sealed ceiling are important in creating an energy efficient residence. High R-values are required because of the large area and high inside temperatures near the ceiling.

The insulation provides most of the thermal resistance in a ceiling. Insulation must be placed between and over joists to provide a high overall R-value. The usual choices are fiberglass batt or blanket, loose fiberglass, or blown-in cellulose.

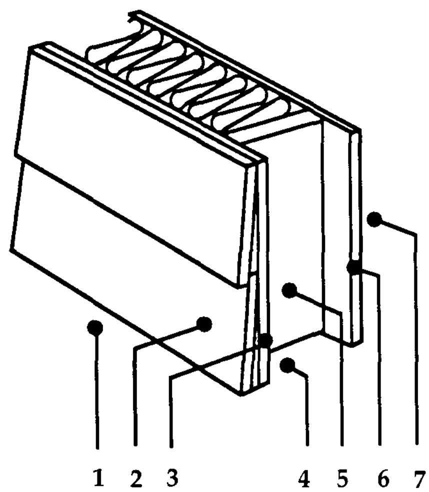
The ceiling should be sealed to prevent inside air from reaching the attic. Inside air that infiltrates the attic will carry moisture that will cause damage as it condenses. Gypsum board or a vapor retarder in the ceiling can provide the air barrier if all penetrations into it — including pipes, vents, lighting fixtures, and chimneys — are properly sealed. Air movement from inside the wall to the ceiling through holes drilled for wiring or pipes should be minimized. Ventilation of the space above the insulation with outside air should be provided to remove water vapor that does enter the attic.

Walls

Because walls account for a large portion of the area of a building envelope, adequate insulation is essential. It is important to have an air barrier to reduce infiltration and a vapor retarder to reduce water vapor movement into the wall.

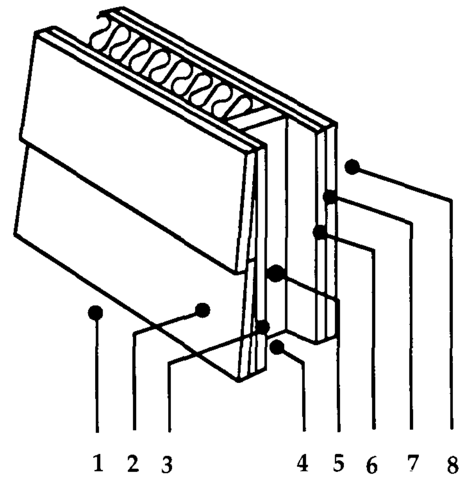
The type and size of framing determine the amount of insulation that can be placed within a wall. A 2x4 stud wall will have space for 3½ inches of insulation (Figure 2). Likewise, a 2x6 stud wall will have space for 5½ inches of insulation (Figure 3). The amount of heat loss through the insulation is usually lower than the amount of loss through the framing. Therefore, it is sometimes desirable to add an insulation board to the framing to increase the total R-value (Figure 4). Most of the thermal resistance of a well-insulated wall comes from insulation, not from the other building components.

Increasing the insulation level of a wall can be a considerable financial investment. It is most practical to add insulation when there is an existing airspace in the wall that is not presently insulated, when planning to



1. Outside surface (15 mph wind)
2. Wood siding, 0.5 inch by 8 inch lapped (average)
3. Sheathing 0.5 inch vegetable fiberboard
4. R-19 mineral fiber batt
5. Nominal 2 x 4 wood stud
6. Gypsum wallboard, 0.5 inch
7. Inside surface (still air)

Figure 3. A 2x6 wall cavity.



1. Outside surface (15 mph wind)
2. Wood siding, 0.5 inch by 8 inch lapped (average)
3. Sheathing 0.5 inch vegetable fiberboard
4. R-11 mineral fiber batt
5. Nominal 2 x 4 wood stud
6. Extra insulation
7. Gypsum wallboard, 0.5 inch
8. Inside surface (still air)

Figure 4. A 2x4 wall cavity with an extra insulation board on the inside.

change the exterior siding, or when planning extensive interior renovation. An existing airspace in a wall can be insulated by blowing insulation in through drilled access holes.

Windows and Doors

Although windows are a small portion of the total wall area, they represent a large source of transmission heat loss because of their low R-value. The Minnesota Energy Code allows up to 10 percent of the wall area in a residence to be glazing (glass) and up to 12 percent if there are sliding glass doors. Windows and doors are also a large source of infiltration within a residence. An important consideration for windows and doors is to have tight seals.

Windows range from single pane with a value of R-1 to multipanes with an insulating value of R-11. A second pane of glass, which may be a tight fitting storm window, is a minimum in Minnesota. Multipane windows provide most of their insulating value by allowing an airspace between the panes. Airflow in the airspace and next to the window should be kept to an absolute minimum. Windows or doors with a metal frame require insulation between the metal on the inside and outside to form a thermal break. Because replacing windows can be expensive, it is difficult to justify economically if increased energy efficiency is the only reason for replacement. Weatherstripping or caulking leaky windows or using an insulated window covering (plastic sheeting or curtains) is an alternative for increasing the R-value.

Weatherstripping at the window and door frame reduces air leakage at points where two surfaces meet and move relative to each other. Caulking where two surfaces meet but do not move reduces air leakage at the sash and at cracks around the window frame.

Glass areas that face south allow solar radiation gain during the winter. Multipane windows increase the thermal resistance of the window but also lower the solar radiation gain.

The Minnesota Energy Code requires that doors have an R-value greater than 3 and allows a maximum door leakage of 0.5 CFM (cubic feet per minute) per foot of door crack. There are doors available that have a value of R-10. Door selection should be based on the relative cost for the rated R-value. Sliding glass doors are a major source of heat loss in terms of both transmission and infiltration. An alternative is an atrium door that opens rather than slides.

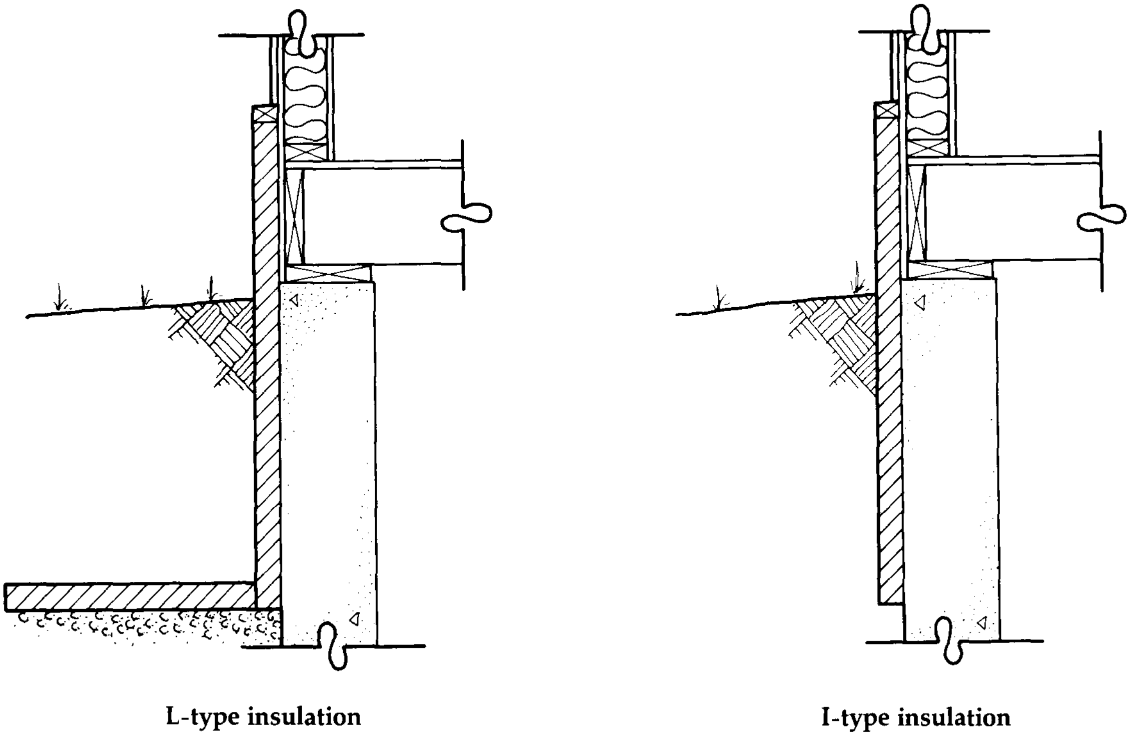


Figure 5. Two common exterior basement insulation placements.

Foundations, Basements, and Floors

Foundation insulation is needed in Minnesota, but determining the amount required is difficult. An uninsulated foundation will result in cold surface temperature inside the residence. The aboveground foundation wall and the exposed floor joists often are major sources of heat loss because of inadequate insulation. All wall sections that are above ground level should be insulated to the same R-value as the framed wall. The exposed portion of the foundation walls and the joist space may have cracks and openings that need to be sealed to reduce infiltration.

The foundation below ground level has a lower heat loss because of the insulating effect of the ground; however, insulation is needed at least to the frostline and is suggested for the entire foundation wall (Figure 5). When there is adequate drainage, it normally is desirable to add insulation to the exterior. Insulation above grade needs to be protected from ultraviolet rays and rodents. If a basement has poor drainage or an owner does not want to dig around the foundation, insulation can be added to the interior. Some types, such as extruded polystryene, require a fire barrier of gypsum board. Recommended insulation levels vary from R-5 for the entire foundation wall to an amount equal to 75 percent of the insulation in the framed wall.

Insulation to a depth of 24 inches around the perimeter is recommended for concrete slabs on grade. The U.S. Department of Housing and Urban Development recommends an insulation thickness of 2 inches of expanded polystryene for slabs and 2½ inches if heating elements are contained in the slab.

Recommendations for a basement floor vary from none to 35 percent of the insulation value of the framed wall. The insulation level of a floor can be increased by adding carpeting or by installing a raised floor.

For additional information, contact your local county extension office and ask for the following publications: *First Things First: What to Do Before Insulation* (HE-FO-0684), *Home Insulation: How to Do It* (HE-BU-1395), and *Economics of Saving Energy: Cash Flow, Payback and Long-Run Result* (HE-BU-1938).

COLD CLIMATE HOUSING INFORMATION CENTER
203 KAUFERT LABORATORY
2004 FOLWELL AVENUE
UNIVERSITY OF MINNESOTA
ST. PAUL, MINNESOTA 55108

Fred C. Vosper is a consulting engineer who specializes in the areas of energy conservation and design. Barbara J. Wiersma is assistant professor and extension specialist, Department of Agricultural Engineering.

Issued in furtherance of cooperative extension work in agriculture and home economics, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Patrick J. Borich, Dean and Director of Minnesota Extension Service, University of Minnesota, St. Paul, Minnesota 55108. The University of Minnesota, including the Minnesota Extension Service, is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, religion, color, sex, national origin, handicap, age, veteran status, or sexual orientation.