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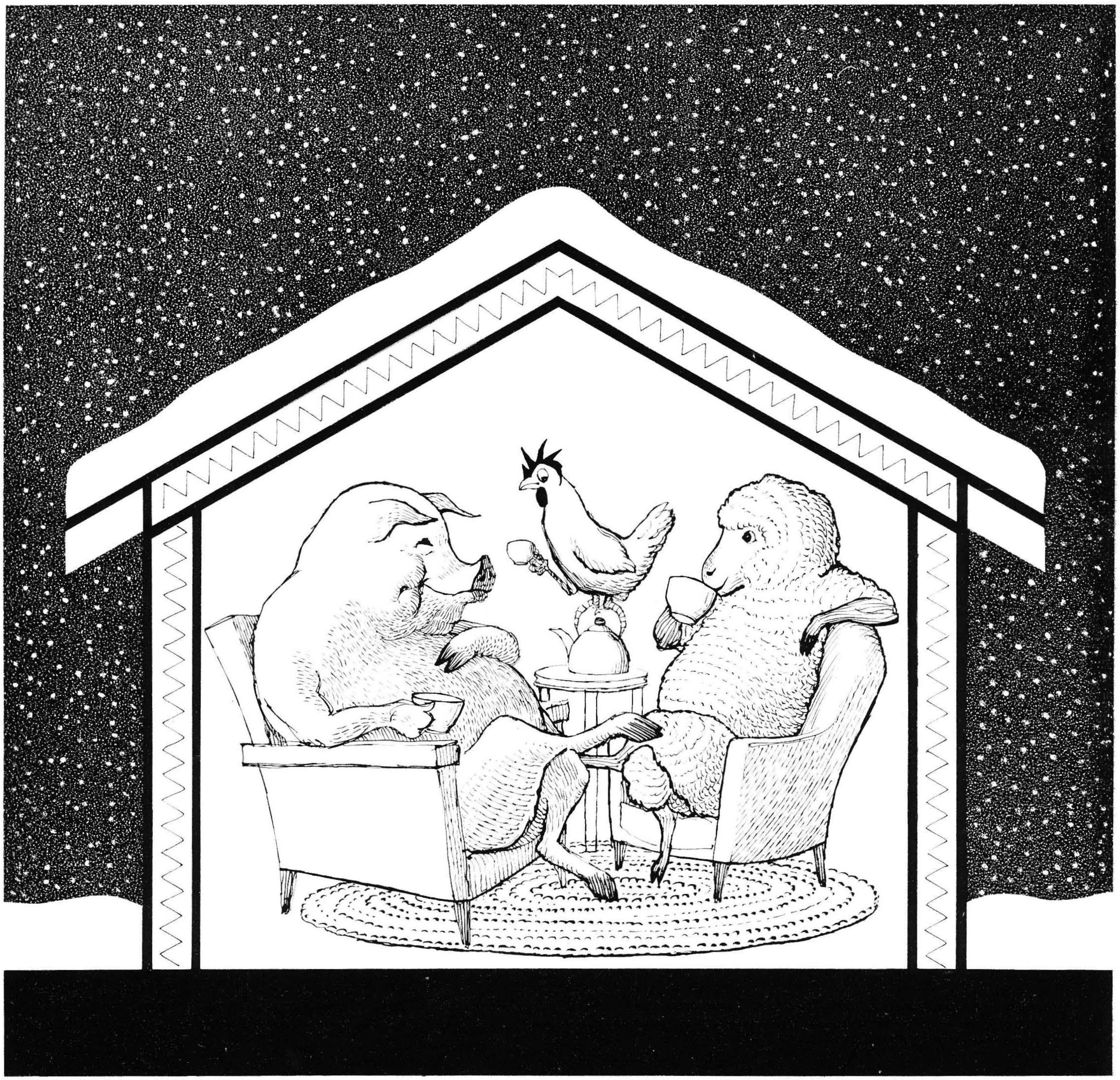

COOPERATIVE EXTENSION SERVICE—MICHIGAN STATE UNIVERSITY—EAST LANSING, MICHIGAN

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Insulation for Farm Buildings

By Edward Kazarian, James Boyd, and Robert Maddex
Agricultural Engineering Department

INTRODUCTION

Michigan people pay millions of dollars each year to be comfortable in cold weather. It is a cost item that no one can avoid as a home owner, farmer, or businessman.

But heating can be efficient and economical. We can control its loss and get the most out of our heating dollar. It requires the right building materials and sound construction.

Insulation is a No. 1 requirement for efficient control of heat loss in buildings. The purpose of this bulletin is to present a general knowledge of insulating materials and an understanding of the basic principles of using insulation. The descriptions, methods and specifications presented here are intended as a guide for selecting and using insulation. No attempt is made to cover every specific insulation problem.

Insulation requirements for some buildings, such as the farm house, depend upon a number of factors. They have to be treated individually. Weather conditions, type of construction, method of heating and fuel costs all influence the type and amount of insulation needed in a house. Insulation requirements of an electrically-heated house, for example, are completely different from those of a house heated with forced hot air.

It is suggested that you discuss special insulation problems with local heating or insulating companies.

HEAT LOSS

The term, heat loss, refers to the movement of heat from warm areas or surfaces to cold areas or surfaces. Heat can be lost from a room by passing through building materials, air spaces and cracks or openings. Insulation itself does not completely stop the passage of heat; it merely reduces the rate of heat movement. When a building is heated, loss of heat occurs in one of the following ways or by a combination of them: (1) conduction, (2) convection, and (3) radiation.

Conduction. This method of heat movement occurs whenever there is direct contact between the hot and cold areas. For example, if one surface of a material (say the inside wall of a milkhouse) is heated, the heat will be conducted through the material to the colder surface.

Convection. When air moves across a hot surface, it becomes warm and rises, thus carrying away heat from the surface. Convection depends on some medium, usually air or water, to convey heat from the warm areas to colder areas.

Radiation. Heat loss by radiation occurs when there are two separate bodies or surfaces at different temperatures. The warmer body or surface will radiate heat to the colder body or surface without heating the air between them. The heat from the sun is an example of radiated heat. Animals can also lose heat by radiation to a colder surface such as a wall or ceiling.

Insulation will reduce the heat loss from a building by any one of the above methods.

INSULATION

The term, insulation, refers to materials which have a high resistance to the flow of heat. Heat does not pass readily through them. Most insulations are fibrous or granular materials that contain many tiny air pockets or cells. Generally, the more air pockets in a material, the better it is as insulation. Some building materials, such as wood, have good insulating properties while others, like concrete, are poor insulators. For example, one inch of wood has approximately ten times the insulating value of one inch of concrete.

Another type of insulation, reflective, consists of metallic (usually aluminum) coated paper or metallic foil. Reflective materials insulate on an entirely different principle from that of fibrous or granular materials. Their effectiveness is based on the fact that polished smooth metallic surfaces reflect radiated heat much like mirrors reflect light. Reflective insullators are effective only if there is an air space on one or both sides of the metallic surface. Hence. reflective insulation should not be placed between sheathing and siding or imbedded in concrete.

WHY INSULATION IS NEEDED

Insulation is used in some farm buildings to provide more comfort in both winter and summer. In winter, insulation provides a more even temperature in the building by reducing the heat loss and by eliminating drafts and cold corners. In summer, insulation reduces the amount of heat entering the building.

Home insulation will reduce the cost of heating or air conditioning, and will soon pay for itself through fuel savings. Also, an insulated house can have a smaller heating plant as compared to the same sized house without insulation.

In animal buildings insulation can increase production as well as decrease sickness and mortality.

Proper insulation and ventilation can reduce or stop condensation or "sweating" in barns and pens.

Other factors that justify the use of insulation in farm buildings are: increased fire resistance, sound proofing and increased building values.

WHERE TO INSULATE

If you plan to insulate any building be sure it is in good condition. Seal all cracks or air leaks in walls, around doors and windows, in ceilings and floors before installing insulation. Caulking, weather stripping, and storm windows, are as important as insulation in keeping heat in a building.

An estimated 30% of the total heat loss goes through the top of the building. If only part of a building is to be insulated, start first with the ceiling or roof. Whether to place the insulation in the ceiling or roof of a house depends on how you want to use the attic space. If you want to heat the attic, then put the insulation just under the roof. In an unheated attic, place it just above the ceiling below.

Farm home insulation should be placed in all outside walls and in walls next to unheated garages and storage rooms. Houses without a basement need insulation in the floor. Floors of rooms over open porches should also be insulated.

In general, insulation should be placed between the heated and unheated areas of a building.

INSULATION MATERIALS

Raw materials used in the manufacture of insulation are classified as follows:

A. Mineral

1. Glass wool
2. Rock wool
3. Slag wool
4. Expanded minerals
    a. Vermiculite
    b. Pearlite
5. Metallic foil

B. Vegetable

1. Cellulose fibers
2. Cork
3. Cotton
4. Paper fibers
5. Wood fibers

C. Plastic (foamed)

All insulation materials in general should have the following properties:

1. Resistance to fire
2. Resistance to moisture and decay
3. Not attractive to vermin and insects

These insulating materials are manufactured into different types or forms such as blankets, batts, etc. The choice of which type to use depends on where it is to be installed and the ease of application.

Figure 1. Leveling fill type insulation placed between ceiling joists.

INSULATION TYPES

Loose fill insulation. Loose fill insulations are bulk materials. They are usually sold in bags, and come in two forms, fibrous and granular. Fibrous materials such as rock wool and glass wool are poured into the framing spaces—where it is practical to do so—or blown into framing spaces with special equipment. Wall spaces in existing buildings may be insulated this way.

Granular insulations like vermiculite and pearlite can be more easily poured into spaces without the use of blowing equipment. Besides filling existing wall spaces, the fill-type insulation can be used to insulate ceilings. The fill is placed between the ceiling joists and leveled off to the desired thickness. See Figure 1. It is important that a vapor barrier (see discussion below) be placed on the warm side of the insulation.

The cores of concrete block walls can be easily filled with granular fill insulation. The fill is poured into the cores as the wall is being constructed (Figure 2).

All fill insulations will settle in time; therefore, insulated spaces should be checked periodically and refilled if the insulation has settled leaving an uninsulated space.

Blanket insulation. Insulation blankets are made by enclosing the insulation materials between two layers of paper. Many manufacturers incorporate a vapor barrier on one side of the blanket. Asphalt-saturated paper or metallic-coated paper on one side make effective vapor barriers.

It is important that the side of the blanket with the vapor barrier is placed to the warm side of the wall or ceiling. The side of the blanket with the thin,

Figure 2. Pouring granular fill insulation into the cores of a block wall.

Figure 3. Providing a nailing flange at the bottom of blanket insulation for nailing to the sill.

usually perforated paper should be placed to the cold side of the wall.

Blanket insulations are manufactured in widths suitable for inserting between the structural framing members of a building. The 15-inch-wide blanket is used for framing spaced 16 inches apart and the 23-inch-wide blanket is used for framing 24 inches apart.

Blankets are provided with a nailing flange on each side so that they may be nailed or stapled to the face or the inside edge of the framing member.

Blankets are available in thicknesses of 1, 2, and 3 inches and in lengths up to 100 feet. This type of insulation is usually installed in walls, ceilings and floors during construction.

In installing the blankets, it is important that the entire opening is sealed. Do this by cutting the blanket 4 inches longer than the length of the space. Then, remove 2 inches of insulation from each end of the blanket to form a nailing flange for nailing at the sill and at the top plate (Figure 3).

Batt insulation. Batt insulation is similar to blanket except that it may not have the enclosing paper on both sides. Some batts have a vapor barrier on one side only. Like blanket insulation, they are installed with the paper on the warm side of the wall. If you use plain batts without a paper covering, be sure to provide a separate vapor barrier.

Batts are manufactured in the same widths and thicknesses as blankets; but they are only 4 feet or less in length. Batts are especially suitable for insulating new construction (Figure 4).

To install batts in walls, start at the bottom, butting successive batts together. Press them tightly together and to the studs to prevent air leakage.

When electrical outlets, pipes or other fixtures are present in the wall space, the insulation can be removed from the batt and placed behind the object. The vapor barrier should be cut to fit snugly around electrical outlets.

Rigid insulation or insulating boards. Some insulation materials, such as wood fibers, are made into rigid boards and used as sheathing, interior finishing boards, insulating planks and various other specialty items. Table 1 shows some of the common sizes and uses of insulation board.

Slab insulations. Slab insulations are small, rigid blocks of some insulating material. The most common materials used for slabs are asphalt saturated wood fibers, cork, glass and plastics. The slab insulations

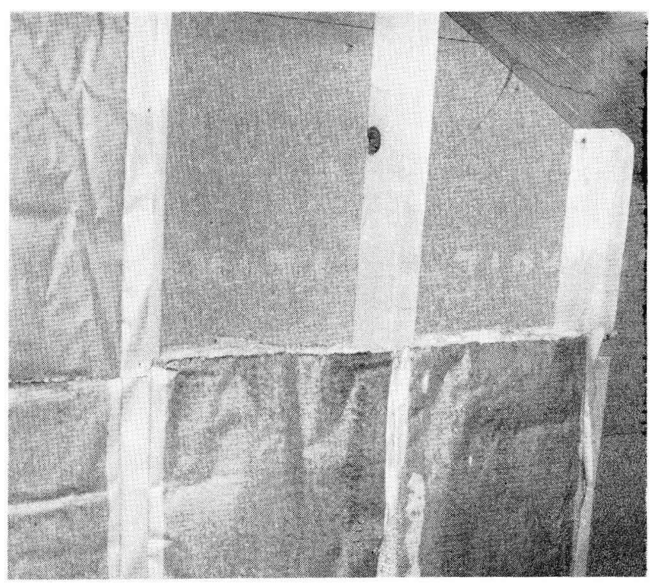


Figure 4. Installation of batt type insulation in a sidewall.

are used primarily in cold storage rooms or for perimeter insulation for concrete slab-on-grade construction. Since they are used in locations where moisture is always present, slab insulations are water-proof and can withstand weather and exposure.

In the construction of cold storage rooms, slab insulations are applied to walls and ceilings with a mastic compound. Thus, there is no need to use furring strips.

For slab-on-grade construction, the insulation is placed around the perimeter of the foundation wall (Figure 5). Perimeter insulation will help prevent cold damp concrete floors, especially around the outside of the building. If the concrete floor is to be heated with floor coils, the slab insulation is also placed underneath the concrete to stop heat loss into the ground.

Reflective insulation. Reflective insulations come in two basic types—a single layer of reflective foil or multiple layers of foil separated by paper folded like an accordion. The accordion-type insulations maintain an air space between the reflective layers of foil and are more efficient than a single layer of foil.

Reflective insulation is sometimes combined with other forms of insulation. For example, one side of a blanket type or rigid type insulation may be lined with metallic foil. It is important, however, to leave an air space next to the metallic surface.

Metallic foils or metallic coated papers are resistant to the passage of water vapor; hence, the reflective insulations also act as vapor barriers. It is important not to break or tear the reflective material when applying it, or its effectiveness as a vapor barrier will be destroyed.

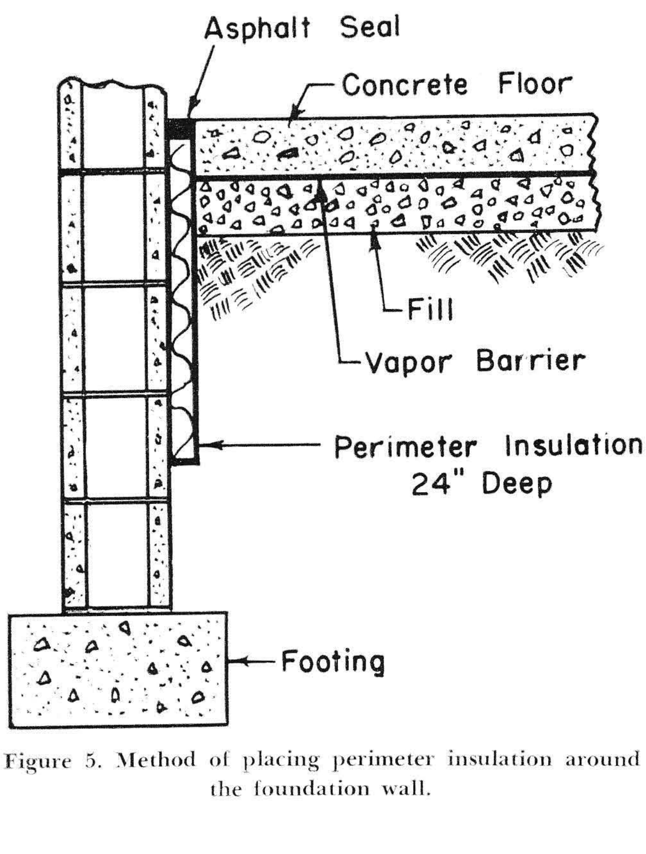


Figure 5. Method of placing perimeter insulation around the foundation wall.

TABLE 1

Sizes and Uses of Insulation Boards

Product	Size	Thickness (in)	Major use
Sheathing	4′ x 8′ 2′ x 8′	1/2, 25/32 1/2, 25/32	Wall sheathing under siding, shingles or brick veneer.
Roof insulation board	2′ x 4′	1/2, 1	Under built-up roofing on flat roofs.
Interior tile	12″ x 12″ 12″ x 24″ 16″ x 16″ 16″ x 32″	1/2	Decorative insulating walls and ceiling in the home.
Interior boards	4′ x 8′ 4′ x 10′ 4′ x 12′	1/2	Several purposes for structural insulating board, can be painted or covered with other finish materials.
Shingle backer	Various	3/8, 5/16	Undercourse for wood or cement-asbestos shingles applied over sheathing.

Other advantages of reflective insulation are: it does not absorb moisture, which would reduce its effectiveness, and it does not store up heat. Also, the reflective insulation will not settle and leave uninsulated gaps at the ceiling level.

When installing reflective insulation in wall or ceiling spaces, place the insulation at the middle of the space as shown in Figure 6. Installed in this manner, the reflective insulation creates two air spaces which keep down heat loss.

Farm-produced insulation. Many materials produced on the farm have good insulation properties. Straw, corncobs, sawdust and wood shavings are good insulators; however, these materials tend to absorb moisture and will lose their insulating value unless they are kept perfectly dry. Farm-produced materials are not fire or rodent resistant, and, therefore, are not recommended unless specially treated. Of these materials, shavings are best, followed by coarsely ground corncobs. Sawdust and straw should be used only as a last resort.

VAPOR BARRIERS

Any insulation in a building must be protected from moisture by a vapor barrier. As previously described, some insulation materials come with a

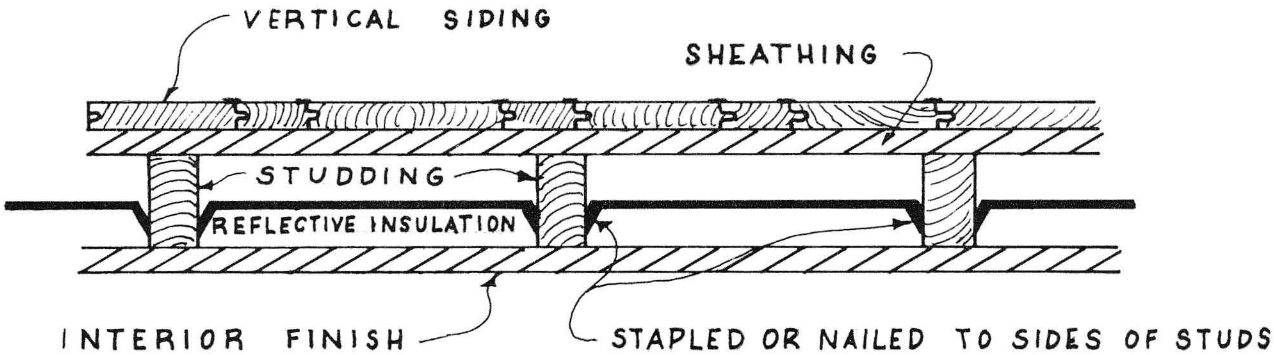


Figure 6. Installing reflective type insulation in the middle of the stud space.

vapor barrier attached. If your insulation does not have its own vapor barrier you must provide a separate one.

Materials used as vapor barriers are metallic foils, asphalt impregnated paper, polyethylene plastic and others that have a high resistance to moisture flow. Enamel or oil paints applied to the inside walls will also serve as a vapor barrier.

Moisture, in the form of vapor, is always present in the air inside buildings. It comes from many sources; cooking, bathing, washing, and wet floors all add large amounts of moisture to the air. In animal shelters, most of the moisture comes from the animal's breath, urine and droppings.

When the amount of water vapor in the air of the building is greater than the water vapor in the air outdoors, the vapor will move from the inside to the outside. This vapor movement is increased when the air is heated because warm air can hold more vapor than cold air. Hence, during the winter, the movement of vapor is speeded up due to the great difference between inside and outside temperatures and condensation may occur. This happens because warm moisture-laden air comes in contact with cold surfaces and condenses the vapor into water. This condensation will occur on the surface or within the walls and ceilings.

The only effective way to combat condensation is to use a combination of insulation and a vapor barrier. In buildings where a large amount of moisture is constantly produced, it may be necessary to ventilate also in order to completely prevent condensation.

VENTILATION OF ATTIC SPACES

The space above an insulated ceiling should be ventilated to remove any moisture which may accumulate there. Louvers at each end of the building will provide good air circulation. A louver area of one square foot for every 250 square feet of attic floor area should be provided.

INSULATION VALUES AND CALCULATIONS

Insulation materials as well as other building materials, are rated according to their ability either to conduct or to resist the flow of heat. A knowledge of these values for different insulating materials can help you (1) compare the effectiveness of the materials and (2) compute the amount of insulation needed and its cost for a given area or building.

The property that expresses the ability of a material to **conduct** heat is termed the thermal conductivity, and is abbreviated by the letter **k.** This **k** value gives the amount of heat (Btu/hr, "British thermal units per hour") that will pass through a piece of material 1 inch thick and 1 square foot in area, when the temperature difference between the two surfaces is one degree Fahrenheit.

These **k** values are used for materials that are uniform or homogenous in cross section, such as concrete, lumber and insulation, etc. Many manufactured materials which have a specific size, such as concrete blocks, asphalt shingles, etc., are given an overall conductivity value for the thickness stated. The letter **C** is used to denote the overall conductivity of such materials and is known as the **conductance.**

It is important to remember that a **k** value is for a 1-inch thickness of material and a **C** value is for a material of any given thickness.

The second method of rating materials is based on their ability to **resist** the flow of heat. Thus, the thermal resistivity (abbreviated by the letter **r**) of a material is a measure of that material's ability to resist the flow of heat. The thermal conductivity and thermal resistivity of a given material are related properties, and if one is known, the other can be found by using the following relationships.

$$k = \frac{1}{r} \text{ and } r = \frac{1}{k}$$

The thermal resistivity of homogenous materials are expressed for a 1 inch thickness. This value varies

TABLE 2

Resistivity and Conductivity of Uniform Building Materials*

Material and Description	Conductivity (k) Per inch thickness	Resistivity (r) Per inch thickness
Building Boards		
Asbestos-cement board	4.00	0.25
Gypsum or plaster board	1.13	0.89
Plywood	0.80	1.25
Wood fiber board (30 lbs./cu. ft.)	0.50	2.00
Wood fiber-hardboard type	1.40	0.72
Insulating Materials		
Blanket and Batt		
Cotton fiber	0.26	3.85
Mineral wool (processed from rock, slag or glass	0.27	3.70
Wood fiber	0.25	4.00
Boards		
Glass fiber	0.25	4.00
Wood fiber (interior finish)	0.35	2.86
Sheathing	0.38	2.63
Boards and Slabs		
Cellular glass	0.40	2.50
Cork board	0.27	3.70
Plastic (foamed)	0.29	3.45
Loose fill		
Mineral wool (rock, slag or glass)	0.30	3.33
Saw dust, shavings, corn cobs	0.45	2.22
Vermiculite (expanded)	0.48	2.08
Wood fiber (redwood, hemlock or fir)	0.30	3.33
Masonry		
Cement mortar	5.00	0.20
Regular concrete	12.0	0.08
Lightweight concrete		
100 lb./cu.ft. density	3.60	0.28
80 lb./cu.ft. density	2.50	0.40
60 lb./cu.ft. density	1.70	0.59
40 lb./cu.ft. density	1.15	0.86
20 lb./cu.ft. density	0.70	1.43
Brick, common	5.00	0.20
Brick, face	9.00	0.11
Stone masonry	12.0	0.08
Plastering Materials		
Cement plaster, sand, aggregate	5.0	0.20
Gypsum plaster, sand, aggregate	5.60	0.18
Gypsum plaster, pearlite aggregate	1.50	0.67
Gypsum plaster, vermiculite aggregate	1.70	0.59
Woods		
Maple, oak and similar hardwoods	1.10	0.91
Fir, pine and similar softwoods	0.80	1.25

*Values in tables 2 and 3 taken from "Heating, Ventilating and Air Conditioning Guide, 1959".

directly with the thickness of the material; for example, 2 inches of insulation have twice the resistivity as 1 inch. Manufactured products which are not homogenous are given an overall value for the thickness stated. This overall value, when expressed for a given product is called the resistance (R).

Again it is important to note that **resistivity** refers to a 1 inch thickness while **resistance** refers to a particular thickness which may be larger or smaller than one inch. The relationship between the conductance **C** and the resistance **R**, is given by:

$$C = \frac{1}{R} \text{ and } R = \frac{1}{C}$$

The thermal conductivity and thermal resistivity for uniform building materials are given in Table 2. The conductance and resistances for non-uniform materials are found in Table 3. In comparing materials for their insulating value, a lower **k** value indicates a better insulation, while a higher **r** value indicates the better insulation. For example, glass wool with a **k** value of 0.30 is a better insulator than sawdust which has a **k** value of 0.45. Or, in comparing **r** values, glass wool has an r value of 3.33 while sawdust has an r value of 2.22.

Air spaces as well as air films on the surfaces of a wall or roof have an insulating value. The resistance of the air film on an inside surface is 0.68 (assuming no wind) and that of the air film on the outside surface is 0.17 (assuming 15 mph wind). Each vertical air space (3/4 inch to 4 inches) has an **R** value of 0.97. Air spaces that have reflective linings on one or both sides are also given different **R** values as shown in Table 3.

You can find the overall insulating value of a wall or roof, composed of several different materials, by using either the conductance values or the resistance values of the individual materials. The following formulas show that it is simpler to work with resistances than with conductances.

To find the total resistance of a wall or roof composed of several different materials, we may label the materials as material 1, material 2, etc. and use the following formula.

$$R_t = R_i + r_1(x_1) + r_2(x_2) + \cdots\cdots + R_o$$

Where: R_t = total resistance of the wall
R_i = inside surface air film resistance
r_1 = resistivity of material 1
x_1 = thickness of material 1
r_2 = resistivity of material 2
x_2 = thickness of material 2
R_o = outside surface air film resistance

The above formula may be adapted for any number and combination of materials. For example, the

TABLE 3

Resistance and Conductance of Building Materials*

Material and Description	Thickness (inches)	Conductance (C) for thickness listed	Resistance (R) for thickness listed
Air Space			
Vertical	3/4 to 4	1.03	0.97
Same with reflective lining on one side	3/4 to 4	0.46	2.17
Same with reflective lining on both	3/4 to 4	0.41	2.44
Air surface films			
Outside surface (vertical)		6.00	0.17
Inside surface (vertical)		1.46	0.68
Flooring materials			
Asphalt tile	1/8	24.80	0.04
Linoleum	1/8	12.00	0.08
Rubber or plastic tile	1/8	42.40	0.02
Masonry Units			
Clay tile, hollow	4	0.90	1.11
Clay tile, hollow	6	0.66	1.52
Concrete blocks, three oval core	4	1.40	0.71
"	8	0.90	1.11
"	12	0.78	1.28
Cinder aggregate	4	0.90	1.11
"	8	0.58	1.72
"	12	0.53	1.89
(cores filled with vermiculite)	8	0.25	4.00
Lightweight aggregate (expanded shale, clay, slate or slag)	4	0.67	1.50
"	8	0.50	2.00
"	12	0.44	2.27
Roofing			
Asbestos-cement shingles	1/4	4.76	0.21
Asphalt roll roofing		6.50	0.15
Ashphalt shingles		2.27	0.44
Built-up roofing	3/8	3.00	0.33
Wood shingles		1.06	0.94
Siding			
Asbestos cement	1/4	4.76	0.21
Wood, 1x8 in. drop		1.27	0.79
Wood, ½x7 in. bevel, lapped		1.23	0.81
Wood, ¾x10 in. bevel, lapped		0.95	1.05

Miscellaneous

For the following materials the total transmittance (U) and the total resistance (R_t) are given

Description	Total transmittance (U)	Total Resistance (R_t)
Single pane windows	1.13	.89
Double pane windows		
¼ in. sealed air space	0.61	1.64
½ in. sealed air space	0.55	1.82
Singlepane with storm sash (avg. value)	0.65	1.54

formula for a wall composed of five different materials would be as follows:

$$R_t = R_i + r_1(x_1) + r_2(x_2) + r_3(x_3) + r_4(x_4) + r_5(x_5) + R_o$$

Note that whenever the resistivity value (r) is used for a material, it must be multiplied by the thickness of that material. For materials that have a resistance value (**R**), the thickness is already taken into account.

For example, find the total resistance of a wall composed of ¾-inch Douglas Fir siding on the outside of the studs and ½-inch wood fiber insulating board as an interior finish. From Tables 2 and 3, the following values are obtained: (x_1 and x_2 are obtained from the given information)

$R_i = .68$

$r_1 = 1.25$

$x_1 = ¾$ or .75 inches

$Ra =$ (resistance of the air space) $= .97$

$r_2 = 2.86$

$x_2 = ½$ or .50 inches

$R_o = .17$

Substituting into the formula:

$R_t = .68 + 1.25\ (.75) + .97 + 2.86\ (.5) + .17$

$R_t = 4.19$

The total resistance (R_t) is used to determine whether or not it is adequate for farm buildings. The recommended total resistance values for insulated farm structures in Michigan are given in Table 4.

The following examples will illustrate the computation of the total resistance for various situations.

TABLE 4

Recommended Minimum "Rt" Values for Michigan Structures

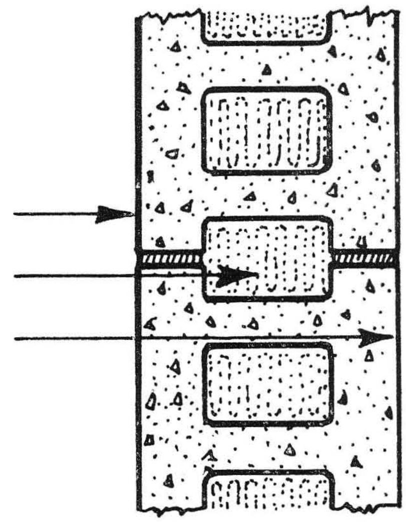
	"R_t" Value	
	Southern Michigan	Northern Michigan
Dairy barn (stanchion)	5.00	7.00
Milkhouse	5.00	5.00
Laying house	10.00	14.00
Brooder house	3.00	3.00
Farrowing house	5.00	7.00
Air-cooled storages	20.00	20.00

For additional information see USDA Misc. Publication No. 633, "Your Farmhouse, Insulation and Weatherproofing."

Example 1

Find the resistance of an 8-inch cinder block wall (cores filled) and determine if the wall is suitable for a milkhouse. The resistance of an 8-inch cinder block (3 oval cores, vermiculite filled) from Table 3 is 4.00. The inside and outside wall surface resistances from Table 3 are added:

Outside surface resistance	0.17
8-inch cinder block (3 oval cores, vermiculite filled)	4.00
Inside surface resistance	0.68
Total resistance	4.85



The recomended resistance for a milkhouse is 5.00 as given in Table 4. The wall resistance of 4.85 is near enough to 5.00 and may be used for a milkhouse.

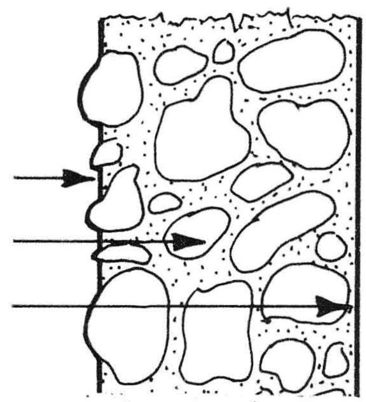
Example 2

Find the resistance of a 16-inch stone masonry wall.

The resistance value of stone masonry concrete per inch of thickness is 0.08 (Table 2). To find the value for a 16-inch thickness, multiply the value per inch times the thickness.

0.08 resistance/inch x
16 inches thick = 1.28
then add the surface resistances.

Outside surface resistance	0.17
16-inch stone masonry	1.28
Inside surface resistance	0.68
Total resistance	2.13

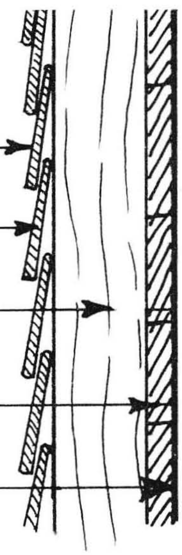


Example 3

Find the resistance of a wall consisting of ¾ inch lap siding on the outside of the studs and ¼ inch wood fiber insulating board as an interior finish.

The values for the lap siding and air space are found from Table 3. The value for 1 inch insulating board is 2.86 (Table 2), therefore, ¼-inch insulating board has a value of .71.

Outside surface resistance	0.17
Lap siding (¾ inch)	1.05
Air space between studs	0.97
Insulation board (¼ inch)	0.71
Inside surface resistance	0.68
Total resistance	3.58



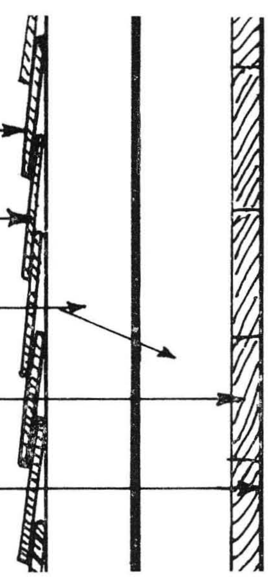
Example 4

Find the increase in the insulating value of the wall described in Example 3 if the single layer of reflective insulation is placed in the middle of the stud space.

The resistance of an air space with a reflective lining on one side is 2.17 (Table 3). Placing the reflective insulation in the middle of the stud space provides two air spaces, each with a reflective lining on one side (total resistance of 4.34).

The total resistance of the wall is:

Outside surface resistance	0.17
Lap siding (¾ inch thick)	1.05
Two air spaces with reflective lining	4.34
Insulation board (¼ inch)	0.71
Inside surface resistance	0.68
Total resistance	6.95

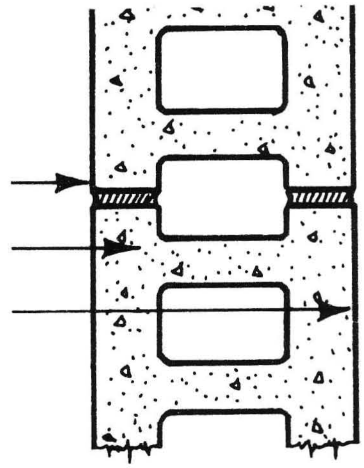


Example 5

How many inches of plastic foam insulation should be added to an 8-inch cinder block wall to provide a total resistance of about 10.

The resistance of the present cinder block wall is:

Outside surface resistance	0.17
8-inch cinder block	1.72
Inside surface resistance	0.68
Total resistance	2.57

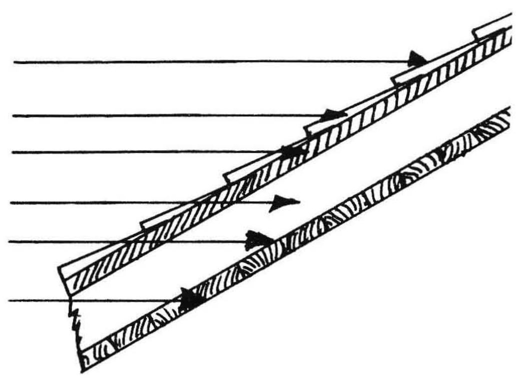


The resistance to be added is the desired resistance minus the existing resistance of the wall or 10.0 − 2.57 = 7.43. From Table 2, the resistance of plastic foam is 3.45 per inch, therefore, 2 inches or a value of 6.90 should be added. This would give a total value of 2.57 + 6.90 = 9.47.

Example 6

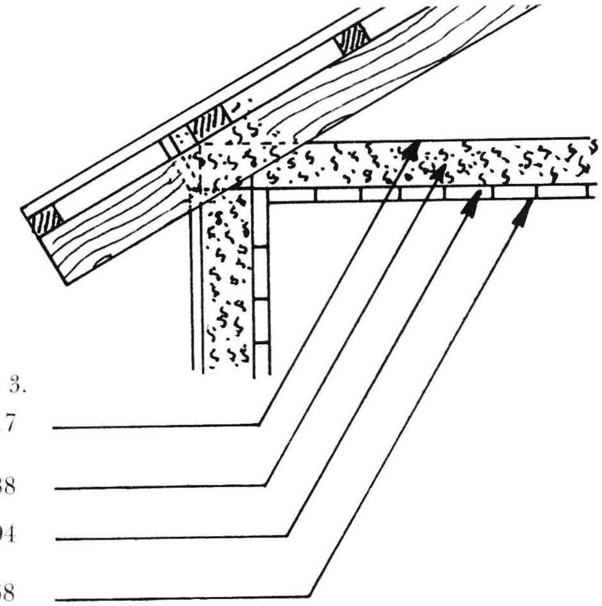
Find the resistance of the roof construction shown. The resistance values are found in Tables 2 and 3.

Outside surface resistance	0.17
Wood shingles	0.94
¾ in. sheathing (fir)	0.94
Air space between rafters	0.97
½ inch insulation board	1.43
Inside surface resistance	0.68
Total resistance	5.13



Example 7

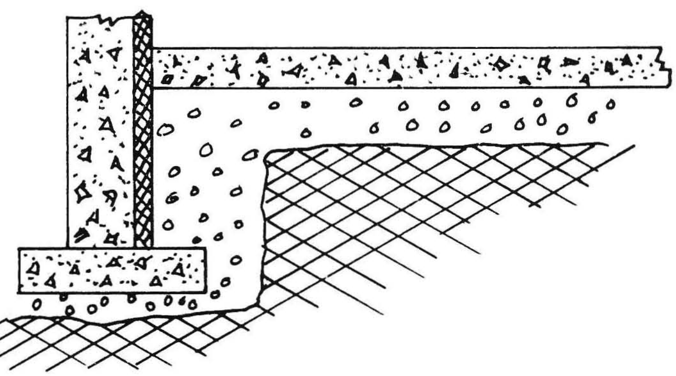
Find the total resistance of the ceiling as shown. The resistance values are found in Tables 2 and 3.



Outside surface resistance	0.17
4 in. wood shavings	8.88
¾ in. sheathing (fir)	0.94
Inside surface resistance	0.68
Total resistance	10.67

Example 8

Find the resistance of a 4-inch bare concrete floor. From Table 2, the resistance of concrete is 0.08 per inch and for 4 inches is 0.32.



Inside surface resistance	0.68
Concrete 4 in.	0.32
Total resistance	1.00

Frequently the thermal transmittance (overall coefficient of heat transfer) abbreviated by **U**, of a wall or roof is desired. The transmittance may be found by taking the reciprocal of the total resistance (R_t).

$$\text{Thus } U = \frac{1}{R_t}$$

HEAT LOSS

Once the **U** value is found, the heat loss through the wall can be computed from the following formula:

$$Q = UA\ (T_i - T_o)$$

where Q = heat loss (Btu/hr.)

U + thermal transmittance of the wall (Btu/hr. x sq. ft. x °F)

A = area of the wall (sq. ft.)

T_i = inside temperature (°F)

T_o = outside temperature (°F)

For example, to find the heat loss through a wall having a U value of .24, an area of 400 sq. ft., an inside temperature of 60°F and an outside temperature of 10°F.

$$Q = .24\ (400)\ (60\text{-}10)$$
$$= .24\ (400)\ (50)$$
$$= 4800 \text{ Btu/hr.}$$

Definitions of Terms and Symbols

Quantity	Symbol	Definition	Units
British Thermal Unit	Btu	Amount of heat required to raise 1 lb. of water 1°F.	
Conductance, Thermal	C	Rate of heat flow through a body of a given thickness and shape	Btu/hr x sq. ft. x °F
Conductivity, Thermal	k	Rate of heat flow through a homogenous body, usually for a one inch thickness.	Btu/hr x sq. ft. x °F/inch
Resistance, Thermal	R	The reciprocal of thermal conductance.	
Resistivity, Thermal	r	The reciprocal of thermal conductivity	
Transmittance, Thermal	U	Rate of heat flow from air on warm side to air on cold side.	Btu/hr x sq. ft. x °F

NOTES

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Other Farm Building Circulars

FBC 712	Farmhouse Plans
FBC 712A	Farmhouse Plans
FBC 714	The Farm Workshop
FBC 718	Laminated Rafters for Farm Buildings
FBC 719	Selecting Joists and Beams for Farm Buildings
FBC 720	Construction of Farm Grain Storage
FBC 721	Farm Fuel Storage
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