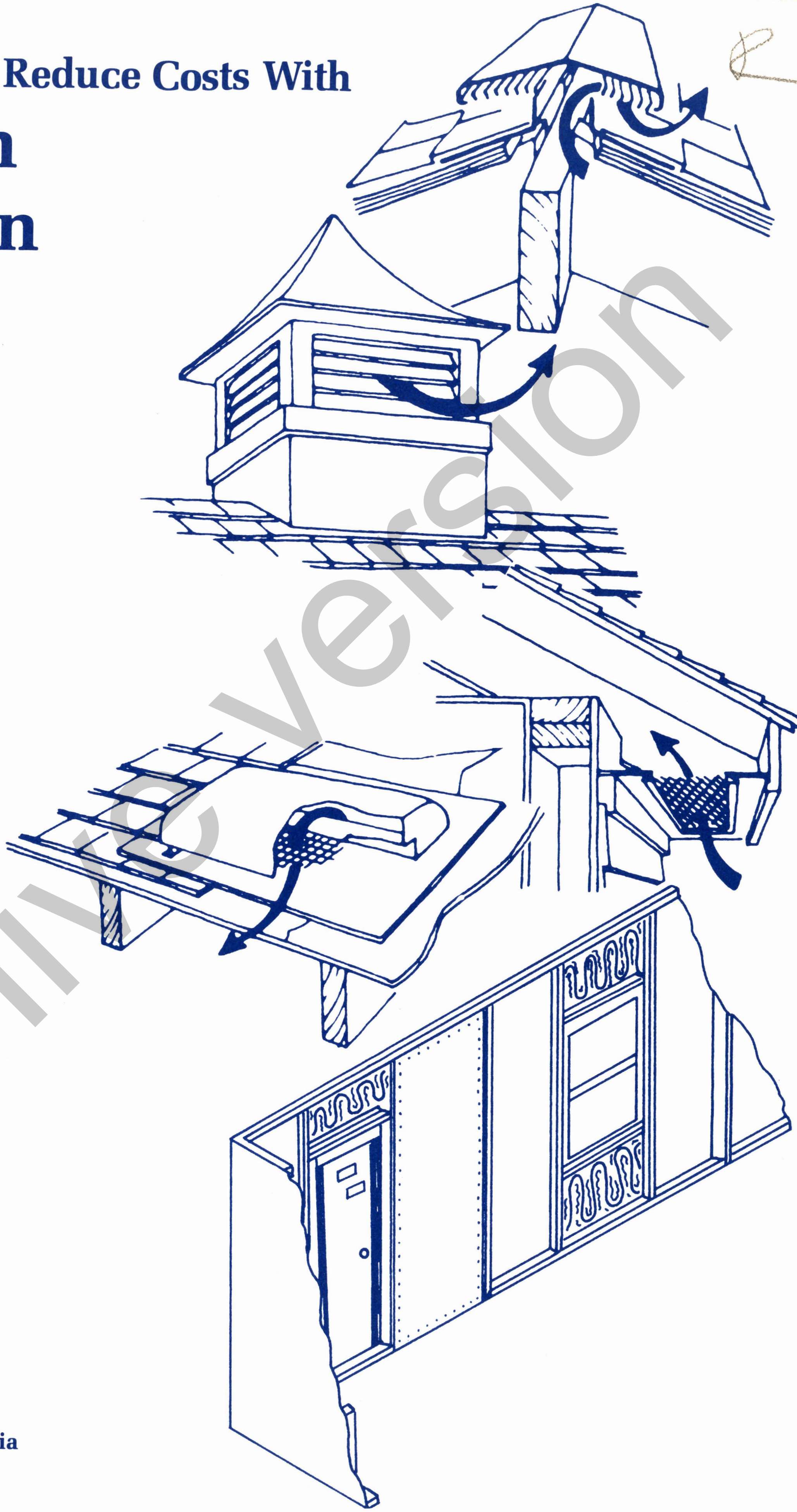
Save Energy and Reduce Costs With

Insulation Ventilation and Moisture Control

For Your Home



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Home Insulation, Ventilation and Moisture Control

Kenneth L. McFate

Careful attention to insulation and ventilation can save you countless dollars in cost of heating and cooling equipment, cost of its installation, and operating and energy costs in the years ahead. To ignore these two factors can be costly not only to you, personally, but to our national resources.

To obtain optimum benefits, however, you must take a personal interest in your construction plans and materials, giving particular attention to heat flow and absorption, and to vapor transfer and cooling equipment characteristics.

HEATING, COOLING, AND NEW HOME CONSTRUCTION

If you're building a new home, site preparation, home location and planning are important to your energy-use future. If you have a choice, locate your house so that the ridge line runs east to west. Place windows on the south to utilize the winter-time solar heat energy; but have enough roof overhang to shade window glass in summer. In most of Missouri, the east-west orientation will allow optimum use of the normally southwesterly breezes. Enclosed porches serve as air traps and reduce air infiltration in cold weather. Surface-mounting electrical outlets also reduces air infiltration. If the outlets are recessed in walls, be sure there is a plastic membrane behind outlet boxes to cut down infiltration losses.

AIR MOVEMENT AND HOME COMFORT

During winter, heat flows from the warm inside wall to the colder exposed surface. In summer, this is reversed but to a lesser degree. Insulation of the proper type and amount will keep winter heat losses and summer heat gains to a practical minimum. Vaporized moisture within the home can be controlled with vapor-resisting materials and proper ventilation. Specific methods of regulating both heat and moisture within the home are outlined in this bulletin.

In winter, we're more comfortable when room surfaces are relatively warm. Body heat doesn't radiate to windows, ceilings, walls, and floors. The indoor *surface* temperatures are determined by the difference between indoor and outdoor air temperatures and the heat transmission characteristics of structural materials between them. With an indoor temperature of 70°F during zero weather, the inside surface of frame walls with 3½ inches of insulation may be 10° warmer than the same wall without insulation. Tightly fitted storm windows often keep the inside of window glass 30 degrees warmer than that of a single-pane glass.

During winter months, home insulation, storm windows, and storm doors not only reduce heating costs but also lower the initial heating equipment investment necessary due to the lower heat energy requirements, and lower connected load (if electric).

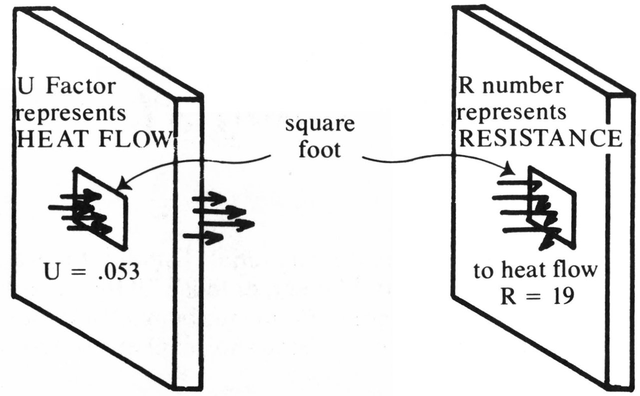
Homeowners will seldom completely design a home but they should have a good general knowledge of the relative importance of different *amounts* and *types* of insulation and how each should be installed. Let's first consider the relative heat resistant values of typical home construction materials.

SOME TERMS OF THE TRADE

Two terms are used to indicate the relative insulating value of materials or sections of walls, floors, and ceilings. One is called the *U factor* and the other, *R number.* The relationship between the two is $U = \frac{1}{R}$. The U factor indicates the *rate* at which heat flows *through* a specific material like that shown in Figure 1. Specific U factors for a number of wall sections are shown in Figure 2. The smaller the U factor, the better the insulating value of the material or group of materials making up a wall, ceiling, or floor. For instance, the first wall section listed in Figure 2 resists heat flow 35 times better than the 8-inch concrete wall, listed last in Figure 2.

The *R number,* also shown in Figure 2, indicates the ability of one specific material, or a group of materials in a building section, to *resist* heat flow through them. The larger the R number, the better the insulating value of the wall component or group of components. Most of the recommended insulating materials have their R number stamped on the outside of the package, batt, or blanket. Figure 3 shows the R number and relative heat resisting values of typical building materials. The R

FIG. 1. U FACTOR AND R NUMBER. The example at right shows a section of insulation with a "U factor" of 0.053. This is a measurement of the rate at which heat will flow through each square foot of the material. The smaller the U factor the better the insulator. The example at right shows a material with an R number of 19 which indicates resistance to heat flow through each square foot of the material. In this case, the bigger the R number the better the material for insulation. Figures 2 and 3 give U and R values for typical building materials.



number for batt, blanket, and loose fill insulation, as listed in this Figure, is for a thickness of 1 inch of dry material. The R number for greater thicknesses can be determined by multiplying the thickness desired, in inches, by the R number shown. (Example: The R number of the 1 inch of wood fiber blanket, near the bottom of Figure 3, is 4. Therefore, the R number for 3 inches is 4 x 3 inches, or R = 12). The insulating values of other wall section materials must be added to obtain the total value for the wall. Remember that the greater the R number, the greater the insulating value of the material and the lower the heat loss in winter and heat gain in summer. A high R number thus means lower heating- and lower cooling-costs with greater human comfort.

FIG. 2—INSULATION VALUES OF TYPICAL WALL CONSTRUCTION (1) (R AND U VALUES)*

CONSTRUCTION DESCRIPTION	INSULATION ADDED	U VALUES	R VALUES	COMPARATIVE INSULATION VALUE
Gypsum board, vapor barrier 1/2 fiber board sheathing, building paper, 3/4 wood siding.	5 1/2 inches of fibrous insulation	0.0440	22.73	
Gypsum board, vapor barrier 1/2 fiber board sheathing, building paper, 3/4 wood siding.	3 1/2 inches of fibrous insulation	0.0598	16.73	
Gypsum board, vapor barrier 1/2 fiber board sheathing, building paper, 4 inch brick.	5 1/2 inches of fibrous insulation	0.0445	22.48	
Gypsum board, vapor barrier 1/2 fiber board sheathing, building paper, 4 inch brick.	3 1/2 inches of fibrous insulation	0.0607	16.48	
8 inch concrete wall, sand and gravel aggregate.	2 inch expanded polystyrene on the exterior	0.1157	8.64	
8 inch concrete wall, sand and gravel aggregate.	2 inch expanded polyurethane on the exterior	0.0761	13.14	
8 inch concrete wall, sand and gravel aggregate.	NONE	1.5625	0.64	

*Assumed wind exposure of 15 mph used in calculating U and R values for wall construction shown. U is the heat loss through each square foot of wall area measured in BTU per HOUR per DEGREE (°F) temperature difference between inside and outside air. R is the resistance to heat loss through each square foot of wall area which is the reciprocal of U.

Selecting and Installing Insulation for Winter Comfort

Several of the insulating materials listed in Figure 3 can be installed in batt, blanket, or loose fill form. Note that the R number is not the same for blanket and loose fill for the same material. Batt and blanket insulation can be installed, by the homeowner, in new construction and in open areas like ceiling or floor sections of remodeled homes.

FIG. 3—RELATIVE HEAT RESISTANCE VALUE FOR SPECIFIC BUILDING MATERIALS*

Material Description	Material Density (lb./cu. ft.)	Material Thickness (Inches)	R Number for Thickness	Relative Value of Resistance to Heat Flow
Building paper	—	—	0.06	
Gypsum plaster, sand aggregate	105	1/2	0.09	
Structural glass	—	—	0.10	
Air surface, 15 mph wind (outside surface)	—	—	0.17	
Asbestos—cement siding or shingles	—	—	0.21	
Gypsum or plaster board	50	3/8	0.32	
Stone, lime or sand	—	4	0.32	
Concrete, sand-gravel aggregate	140	4	0.32	
Built-up roofing	70	3/8	0.33	
Brick, face	130	4	0.44	
Air surface, still air, horizontal ordinary materials, heat flow-up	—	—	0.61	
Plywood	34	1/2	0.62	
Air surface, still air vertical, ordinary materials, heat flow, horizontal	—	—	0.68	
Wood siding, bevel, 1/2″ x 8″, lapped	—	—	0.81	
Wood shingle siding, 16 in. 7 1/2″ exposure	—	—	0.87	
Oak, maple and similar hardwoods	45	1	0.91	
Air space, vertical, ordinary materials, horizontal heat flow	—	3/4-4	0.97	
Clay tile, one cell deep	—	4	1.11	

*From Chapter 24, Reference No. 1.

FIG. 3—RELATIVE HEAT RESISTANCE VALUE FOR SPECIFIC BUILDING MATERIALS (CON'T.)

Material Description	Material Density (lb./cu. ft.)	Material Thickness (Inches)	Material for Thickness	R Number Relative Value of Resistance to Heat Flow
Concrete block, 3 core, sand-gravel aggregate	—	8	1.11	
Acoustical tile, wood or cane fiber	—	1/2	1.25	
Fir, pine & similar softwoods	32	1	1.25	
Insulation board, impregnated	20	1/2	1.32	
Concrete, lightweight aggregate (expanded shale, clay, slate, slag)	80	4	1.60	
Air space, vertical, bounded by reflective material	—	3/4-4	1.70	
Concrete block, 3 core, cinder aggregate	—	8	1.72	
Concrete block, 3 core, lightweight aggregate	—	8	2.00	
Vermiculite, expanded	7.0	1	2.13	
Carpet & fibrous pad	—	—	2.08	
Cellular glass insulation board	9.0	1	2.63	
Mineral wool, loose fill, from slag, glass or rock	0.6-2.0	1	3.15	
Wood fiber, loose fill, redwood, hemlock or fir	2.0-3.5	1	3.33	
Plastic, foamed	1.62	1	3.45	
Macerated paper or pulp	2.0-3.5	1	3.57	
Corkboard, without added binder	6.5-8.0	1	3.70	
BATT & BLANKETS, BOUNDED BY NON-REFLECTIVE MATERIAL				
Mineral wool, fibrous form (rock, slag or glass)	0.3-2.0	1	3.53	
Wood fiber, multilayer, stitched expanded	1.5-2.0	1	3.70	
Cotton fiber	0.8-2.0	1	3.85	
Wood fiber	3.2-3.6	1	4.00	
PLASTIC BOARD				
Expanded polystyrene**	1.6	1	4.00	
Expanded polyurethane	1.5-2.5	1	6.25	

**Conductivity decreases as cell size decreases.

When insulation is installed in irregular areas, as shown in Figure 4, the areas must be given careful attention. At the top and bottom of wall cavities (spaces between the studs), blanket-type insulation should be covered with 4 mil polyvinyl vapor-proof material stapled to structural members. Insulating material should be carefully fitted around all plumbing, wiring and other projections, maintaining proper thickness throughout walls, ceilings and floors. Use non-hardening butyl or silicon caulking to fill all cracks around utility lines, vent pipes, and potential air leakage around windows and other points. Reduced infiltration cuts energy use.

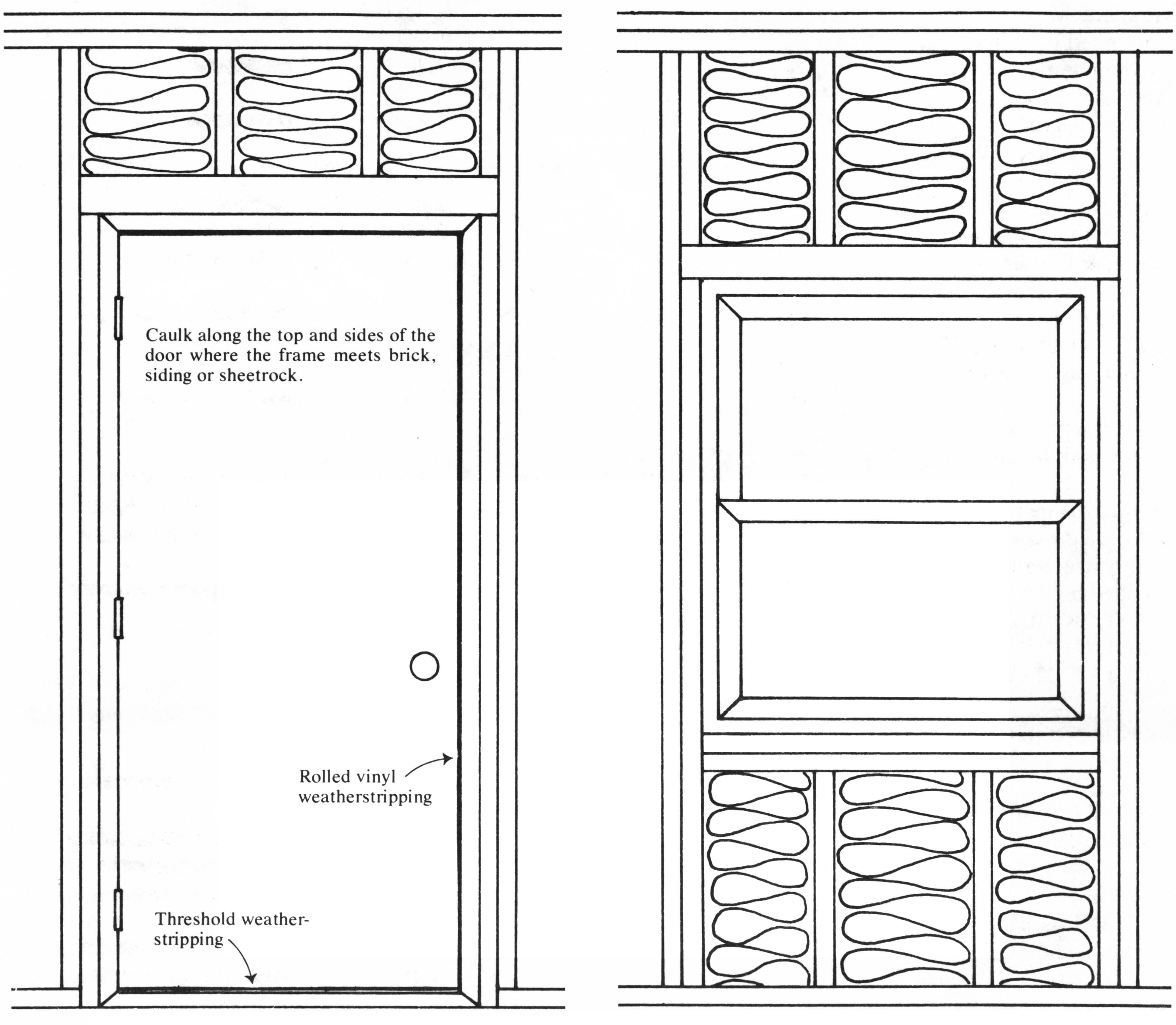
To get the most value from *reflective* insulation materials, such as the aluminum foil facing on batts or blankets, allow a 3/4-inch air space between the foil and the wallboard.

Loose fill insulation, for either new or remodeled homes, must be blown into the walls, floors, and ceilings with special equipment used by competent, reliable operators so that the proper density (lbs. per cu. ft.) of the insulation will be obtained.

To obtain the insulation R-value specified in Figure 3 for any loose fill material, the applicator must use the proper air-insulation mixture to obtain the density stated and to minimize "settling." Note that the desirable density varies with materials.

Insulation should be blown into each wall cavity at both top and bottom (or at center blowing downward) so that all spaces will be filled with a uniform density. As variations in insulation density will affect the heat resistant value and R number of the material, do not employ an applicator with questionable credentials.

Fig. 4—Irregular Areas Require Special Attention.



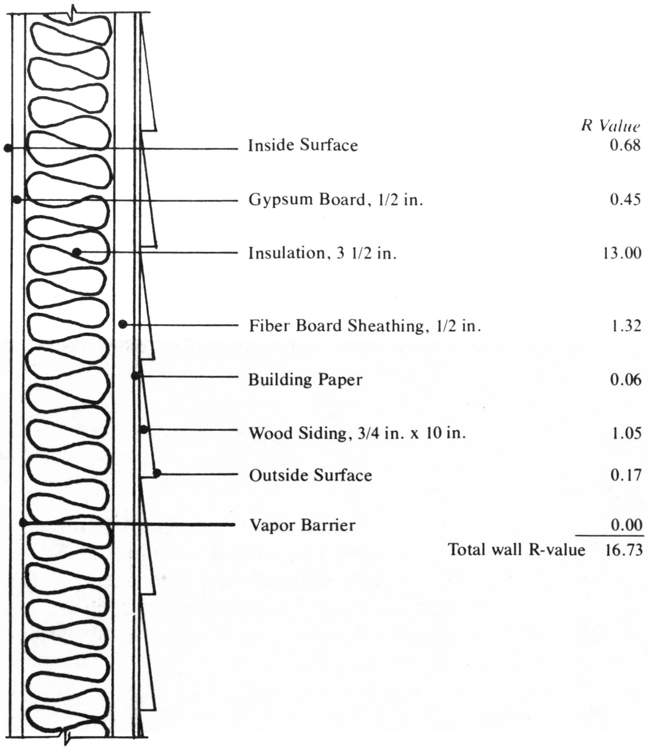


Fig. 5A—Thermal resistance of nominal 4 inch stud wall.

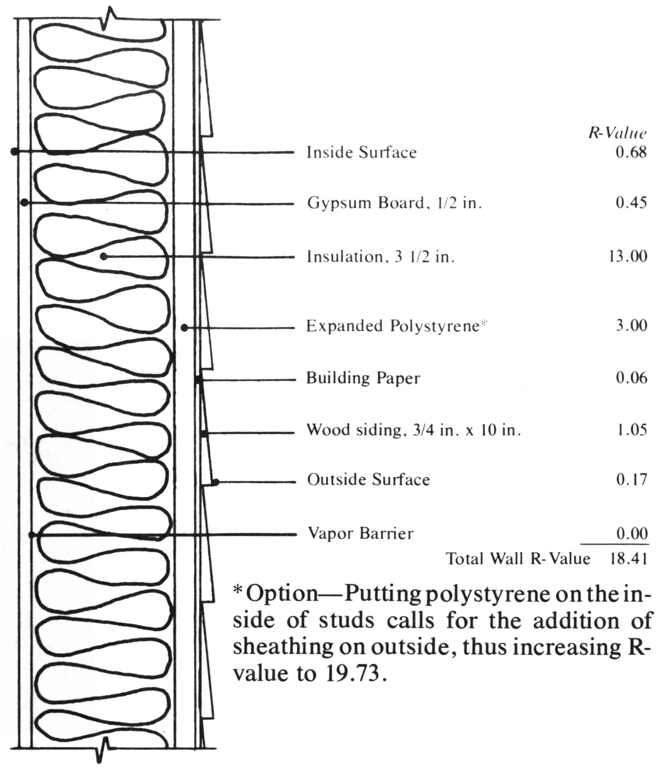


Fig. 5B—Thermal resistance of nominal 4 inch stud wall with polystyrene on outside.

HOW MUCH INSULATION

Any insulation will resist heat flow in proportion to its R number *ONLY* if it is installed according to sound recommendations and/or manufacturer's instructions.

Figure 5 shows the insulating values and R numbers of three different wall sections with various construction types and amounts of insulation, properly applied. This also shows the R number of each material in each wall. The heat loss through the wall section with 5 1/2 inches of insulation (Fig. 5C) is about 26 percent less than it is through the wall section containing only 3 1/2 inches of insulation shown in Figure 5A.

Based on normal Missouri seasons (winter heat losses and summer heat gains), the minimum R-values and the recommended R-values for insulated wall sections, and for the insulating material itself, are shown in Table 1 (page 8). The higher R-number shown is recommended on the basis of energy conservation, electrical load management and future heating and air conditioning cost predictions. In colder climates, more insulation may be justified economically, as illustrated in Figure 6. When homes are "Super-insulated with 3/4 to 1 inch thick tongue and groove foam board, with no plywood or wood sheeting underneath, walls must be braced under the sheeting to give adequate structural strength (see Figure 6).

OTHER HEAT LOSSES

Windows and doors can be sources of large heat-energy losses—not only due to high heat loss through them, but also due to high infiltration when the windows

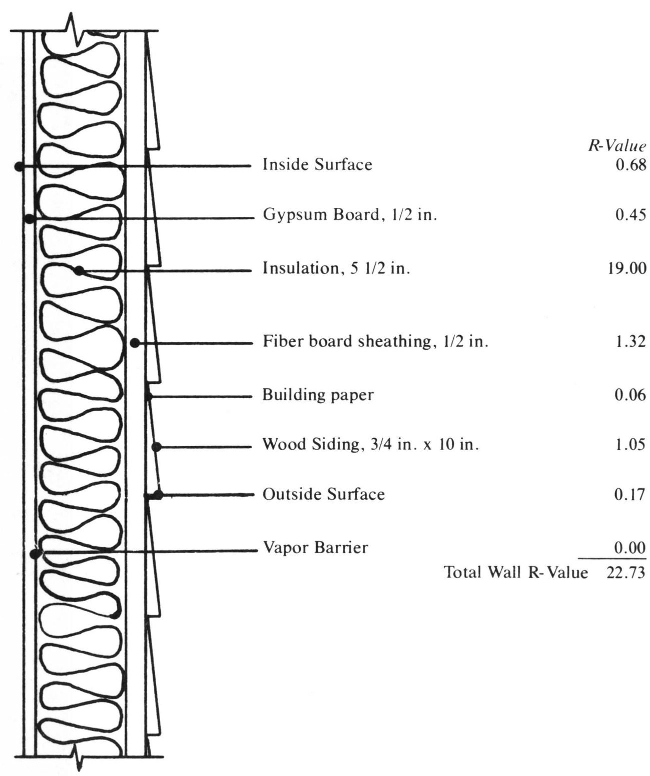
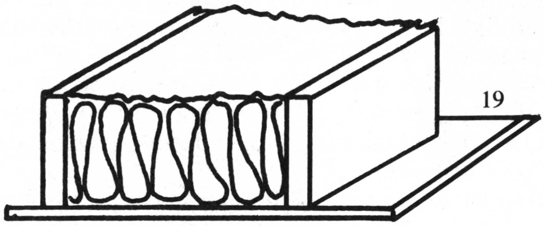
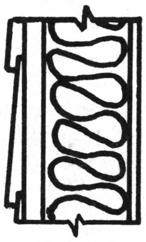
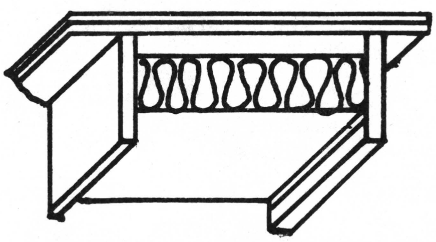
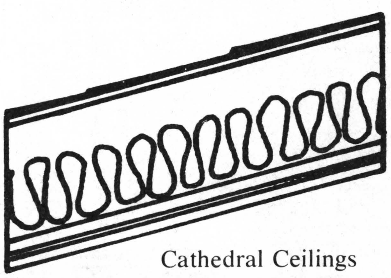
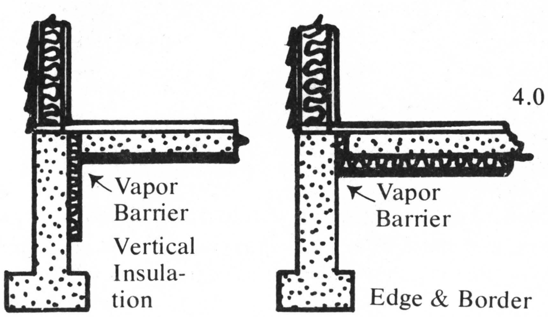


Fig. 5C—Thermal resistance of nominal 6 inch stud wall.

TABLE 1. MINIMUM AND RECOMMENDED R-VALUES FOR INSULATION MATERIALS IN SPECIFIC BUILDING SECTIONS

Building Section	R No. for Insulation Required Minimum	Recommended	
 Ceiling	19	30	This insulation will be 6 or more inches in thickness. For flat or low pitched roofs, rafters should be of 2 x 8 material to accommodate the required 6′′ of insulation and allow sufficient ''breathing'' space between the insulation and exterior parts of the roof.
 Exterior Wall	13	19	An insulation material with an R number of 19 is recommended. A material 3½ to 5½′′ thick will generally be used. A foil surface is not recommended if plastic vapor barrier is used or if no air gap is planned.
 Floors Over Crawl Spaces and Unheated Basements	19	19	Here an insulating material with an R number of 19 is recommended as the temperature in properly ventilated crawl spaces may be only slightly less than the outdoor temperatures. The insulation will be 5 to 6′′, depending upon type of insulation used. Select insulation that fits the spacing of floor joists and place the vapor barrier near the warm or upper side. Use wire mesh or other inexpensive material to hold insulation in place. Commercial steel wire supports are available.
 Cathedral Ceilings	19	30	Due to limited space between the roof deck and the ceiling, this generally limits the amount of insulation that can be applied between rafters to 6′′ batts. However, adding a 5/8′′ to 1′′ rigid foam board insulation to the interior surface, prior to the drywall, will increase the R value.
 Concrete Floors	4.0	8.0	Concrete slab floors should have a 2′′ thick waterproof insulation board between the entire outside edge of the slab and the foundation. This should either extend vertically 24′′ below grade or around the edge and 24′′ horizontally and under the slab. Basement floors less than 2 feet below ground level should also be insulated in this manner.

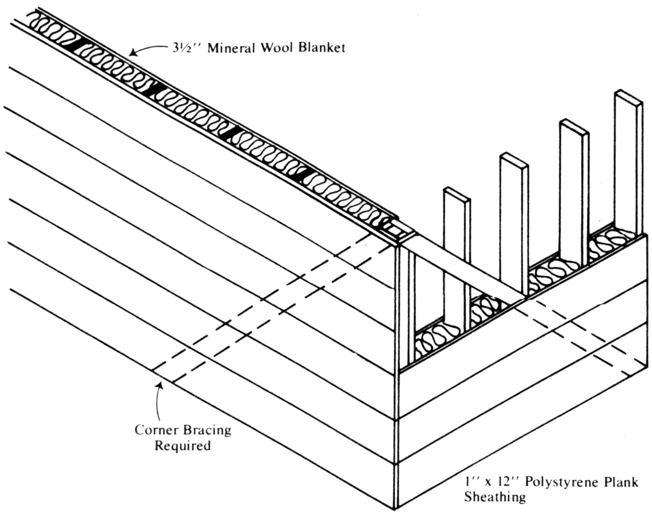


Fig. 6—"Superinsulated" home—3½ inch mineral wool blanket with 1" polystyrene tongue and groove plank. (Wall "R" = 20.)

and doors are opened. These openings should command especially careful attention.

If room temperature is maintained at 70°F, the surface temperature of a single-glass window may be as low as 17°F during zero degree weather. If the window is a double-glass, separated by a 1/2-inch or greater air space, the surface temperature on the interior glass surface will be over 50°F.

In many homes built after 1975, triple glazing has been rather common. And with annually increasing energy costs, their higher cost (over double glazing) can normally be justified.

With such temperature differences (and proportionate heat losses), it is best to keep the glass areas in homes to a reasonable minimum. A good rule of thumb: calculate and/or design for window area to be no more than 12% of the living area (in sq. ft.). And whenever possible, place windows facing south so as to take advantage of solar heat energy during winter.

Use double-glass or triple-glass windows and storm doors. Wood sash storm windows allow less heat loss than metal frame windows or doors. Avoid the so-called

Fig. 7—All fireplace dampers should be tight-fitting and closed when not in use. Any new fireplace should be equipped to draw combustion air directly in from outdoors, should be equipped with glass doors, and should have a heat exchanger unit equipped with proper size of fans.

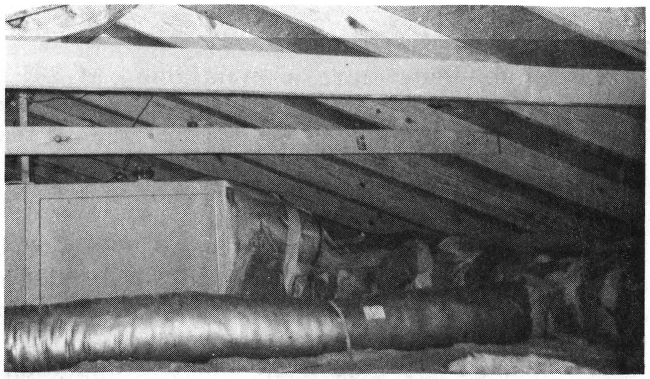


Fig. 8—Insulated heating and cooling ducts in unconditioned spaces conserve energy.

"bargain price" aluminum windows and doors. Snug fitting weather-tight exterior doors and windows are essential to control air infiltration when conserving energy for heating or air conditioners. A styrofoam or urethane foam core main door is preferred and all doors leading to garages, storage areas, and other spaces not heated or cooled should also be weather stripped and preferably equipped with storm doors.

Casement windows have less crack area, which normally reduces infiltration. Interior windows must fit tight to avoid condensation on the inside of the storm window.

Fireplaces add much to a home's beauty and modern living but they also contribute to large heat losses if not properly constructed and managed. Keep losses from this source to a minimum by providing tight-fitting fireplace dampers. Keep them closed when the fireplace is not in use. Reduce heat loss further by using glass fireplace doors and duct outside cool air directly to the front of the combustion chamber. This "make-up" air inlet duct should have an adjustable damper.

WHAT IS ADDITIONAL INSULATION WORTH?

The rate of heat flow from a room is different for each path that it might follow—through studs, joists, glass areas, insulated portions of walls, floors, and ceilings, or through cracks around windows, doors, and other openings. In conventional home construction, there is little that can be done to reduce losses through studs and joists; but there is much that can be done about other losses.

When forced air heating systems are used, any air ducts located outside of conditioned space must be given special attention. One method of insulating such heat ducts is shown in Figure 8.

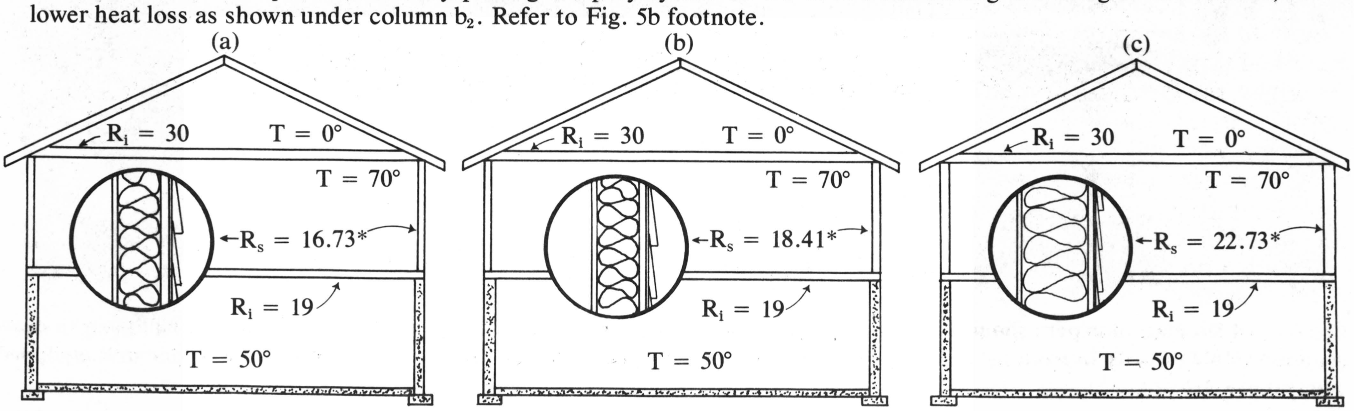
Figure 9 illustrates heat losses of a central Missouri home. The R numbers for the walls were the same as

FIG. 9—RELATIVE HEAT LOSSES IN CENTRAL MISSOURI HOME WITH 1200 SQUARE FEET OF FLOOR AREA AND AN UNHEATED BASEMENT.*

Source of Heat Loss	Exposed Area (ft²)	(a) Heat Loss (Btu/Hr)	(b_1) Heat Loss (Btu/Hr)	(b_2)** Heat Loss (Btu/Hr)
Ceiling	1,070	2,497	2,497	2,497
Walls	890	3,724	3,384	3,158
Windows-Doors	165	5,340	5,340	5,340
Floors	1,070	1,126	1,126	1,126
Framing	230	2,145	2,145	2,145
Total Heat Loss		14,832	14,492	14,266
Loss/sq. ft. Floor Area		12.36	12.08	11.89

*Based on temperature differentials shown on sketch. The wall R-values were taken from Figures 5a, b and c.

**The wall R-value of b_1 is increased by placing the polystyrene on the inside and adding sheathing to the outside, thus a lower heat loss as shown under column b_2. Refer to Fig. 5b footnote.



*R values- refer to Fig. 5A, B, C. These are R-values for insulated wall sections on which comparisons have been made. Stud treatment differences are not accounted for in such comparisons.

R_s = R-value for insulated wall section. R_i = R-value for insulation material.

those of Figures 5A, B, and C. The R numbers for the floor and ceiling were assumed to be 19 and 30, respectively. The temperature in the unheated basement was assumed to be 50°F.

With electricity from 4 to 7 cents per KWH and with central Missouri homes using about 8 KWH per square foot of heated floor area in a normal season, the cost of heating the home in Figure 9C, fully insulated, would be from $380 to $670 per season. Seasonal costs for both can be adjusted, proportionately, with local rates.

Increasing the insulation in the ceiling from R-30 to R-38 would decrease the heat loss by 21% in the ceiling. Using average 1980 retail prices in mid-Missouri, the additional cost of insulation is estimated at 3 cents per square foot. The reduced heating cost will pay for the additional insulation in about one year. Other benefits of proper insulation come through lower fixed cost of heating and cooling equipment and lower operating costs for air conditioning equipment.

WHOLE HOUSE OR ZONE COMFORT CONDITIONING

While a majority of homes have a central heating and/or air conditioning system, all rooms in most homes are normally kept at one temperature, whether or not people are living, sleeping, or working in them. While registers can be used to limit air flow into a specific room, adjustments are normally not made because of (1) inconvenience and (2) because duct pressure changes adversely affect overall efficiency. If the air conditioning source is a heat pump, such air adjustments should not be made. Restricted air flow can lead to higher compressor head and lower efficiency, which increases operating costs.

In contrast to central systems, zone comfort conditioning equipment (heating or cooling) with individual room control has the flexibility and capability of providing just the right amount of heat—warm for living areas where people are relatively inactive, cool for working areas (i.e., kitchen and laundry) and for sleeping areas.

Zone systems can be designed for individual room temperature control or for area temperature control. Electric equipment such as baseboard, ceiling cable heat units and/or small window or through-the-wall air conditioners are ideally suited to meet the needs of room-by-room control. Their installed costs compare favorably with central systems. *Area* control may incorporate two small "central-type" systems; one for working-living areas and one for sleeping areas. Their combined installed cost will be greater than a large central system or the room-by-room electric unit system.

Three advantages of zone control comfort conditioning systems are: (1) possible lower energy use and, consequently, lower heating/cooling costs, (2) lower connected electrical load, assuming both are properly designed, and (3) a lower demand upon the electric power system due to the diversified (different operating times) use of several smaller heating units.

This latter point is becoming extremely important as consumers turn to electric energy in their attempt to conserve the less plentiful fuels (oil and gas) for powering food-producing and other mobile equipment. At a time when the electric industry faces restrictive sociological, physical, and financial conditions which delay the timely development and operation of new generation facilities, the consumer must better manage large electrical equipment (over 2000 watts) so as to help improve efficiency and productivity of present generating equipment. Thus, prudent selection and use of heating and cooling equipment will not only save the user energy but can affect future electric bills through lower demand costs.

SUPER-INSULATED HOMES

With rising costs of energy in all forms, more people are turning to super-insulated homes. One such home (called the Arkansas home as it was first constructed there) uses nominal 2 x 6 stud walls to accommodate 6″ batt insulation and a special roof truss design (see Fig. 10) to accommodate up to 12″ of insulation throughout the entire ceiling area.

Another common practice is to use a 3/4″ to 1″ thick foam board on the outside of a conventional 4″ wall (Fig. 5B). With such foam being resistant to moisture transfer, it becomes especially important to have a good vapor barrier on the warm room side (winter) of every exterior wall.

A third type of "super-insulated" home is one which uses a double 4″ wall (nominal) allowing about 8″ of wall insulation. The double wall construction has the advantage of minimizing infiltration; and it is adaptable to improving the energy efficiency of older homes with otherwise solid construction. Plans for such construction can be obtained from the Small Homes Council, University of Illinois, Urbana, Illinois.

A more recent innovation is the "earth-contact" home. While these have many different construction

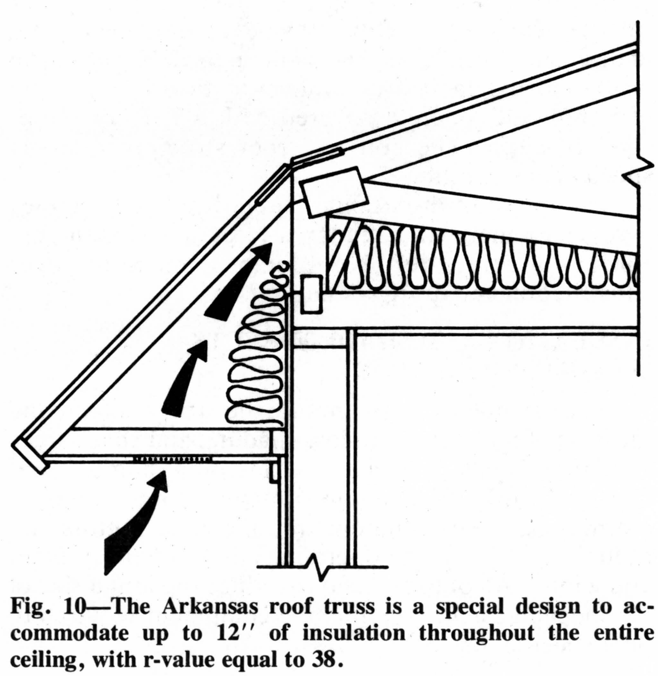


Fig. 10—The Arkansas roof truss is a special design to accommodate up to 12″ of insulation throughout the entire ceiling, with r-value equal to 38.

Fig. 11—"Earth-contact" homes are recessed into an earthen berm or mound. (This one has a special above-ground addition.)

features, such homes are usually recessed into an earthen berm or mound. They are usually open to southern exposure, and have walls made of concrete with graduated thicknesses of sprayed foam on the exterior surface. The roof structure may be rather conventional in design (as seen in Fig. 11) with up to R-38 value attic insulation and good structural ventilation; or it may be of reinforced concrete covered with a 3 ft. (or more) layer of earth. The concrete roof structure requires special consideration.

The intent in discussing "super-insulated" homes here is to make the reader aware of such energy-conserving structures. No attempt is made to cover construction and design details.

INSULATION AND SHADE EFFECTS ON SUMMER COMFORT

The orientation of the home, the size, number, and location of windows, window shading, and shade trees contribute much to energy conservation, human comfort, and work efficiency in summer. Storm windows, storm doors, and insulation are, of course, factors that reduce energy use and operating costs in both summer and winter. All of these tend to reduce the initial size of the mechanical air conditioning equipment required to do a specific job.

Understanding certain conditions is essential. For instance, a south or west facing window with tight storm window might act as a solar collector which would add to summer heat gain. Shading is important in home planning. Keep in mind that a 2 ft. roof overhang is required to prevent most of a mid-Missouri 4:00 p.m. summer sun from falling on south windows.

Air conditioners are normally rated by their heat removal capacity (BTU/hr.). Older units were rated in tons with each "ton" equal to 12,000 BTU/hr. In selecting units today, compare before buying. Look for those with a high EER (Energy Efficiency Ratio) or check the Seasonal Energy Efficiency Ratio (SEER). A Department of Energy efficiency rating tag is mandatory on major appliances, as of May 19, 1980.

Air conditioners dehumidify the air as well as cool it. The best performance occurs when the unit is sized to calculated heat gains, such that it will run almost constantly on the hottest summer day.

Table 2 shows some of the many ways that moisture enters a home. These amounts of moisture produced by each household activity were determined by a Purdue University Engineering Experiment Station study (2) with four members in the family. Larger families would, of course, generate greater amounts of moisture.

TABLE 2—MOISTURE PRODUCED BY HOUSEHOLD ACTIVITIES
(Family of Four)

Activity	Pints of Moisture	Grams of Moisture
Floor mopping (per sq. ft.)	0.03	13.61
Clothes drying (by hanging indoors, per week)	25.32	11974.8
Clothes washing (per week)	4.15	1964.1
Cooking (per meal)		
Breakfast	0.86	408.2
Lunch	1.12	530.7
Dinner	2.58	1220.2
Dish washing (per meal)		
Breakfast	0.19	90.7
Lunch	0.14	68.0
Dinner	0.62	294.8
Bathing (per shower)	0.48	226.8
(per tub)	0.12	54.4
Breathing and perspiring (4 persons, per hour)	0.44	208.6
House plants (each, per hour)	0.04	18.1

RELATIVE HUMIDITY

All air contains invisible moisture called water vapor. Warm air can *hold* more moisture than cold air. The *relative humidity* of the air indicates the amount of water vapor that is being held by the air at a particular time and temperature. Therefore, *relative humidity* is the percentage of water vapor in the air, expressed as a percentage of the maximum amount of water vapor that the air *could* hold at that temperature before condensing out as water.

At 70°F, the air in a 1200 sq. ft. home (8-foot ceiling height) will hold about 1 pint of water at 10 percent relative humidity, 3.6 pints at 35 percent, and over 7 pints at 70 percent relative humidity. During a day's time, we may add as much as 25 pints of moisture from ordinary household activities such as those listed in Table 2.

Health and personal comfort can be adversely affected when amounts of water vapor in the air are *too low.* Symptoms of low humidity atmosphere are dry and irritated nose and throat, cracks in floors, separation of furniture, and a build-up of static electricity. In homes heated with fuel-fired heating systems, air is usually drawn from the house to maintain the combustion process. This air, with its water vapor, is then exhausted through the chimney or flue vent pipe. As the incoming colder air is warmed, its relative humidity is lowered. As a result, wintertime relative humidities as low as 10 percent are often found in these homes, *unless* some means of adding water is provided.

With electrically heated homes, a somewhat different condition exists. No moisture is removed from the air due to combustion. Higher relative humidities result. If the relative humidity is *too high,* this can have adverse effects also. Though a relative humidity of 70 percent in a 70°F home during winter months may be beneficial to some occupants, especially sick people, such high levels can cause damage to the structure. Thus, relative humidities must be controlled.

WHAT LEVEL OF HUMIDITY?

From a health and comfort standpoint, a relative humidity from 35 to 40 percent is considered satisfactory for most people. From the structure standpoint, this is a practical level for electrically heated homes during most of the heating season. At this level, occupants feel comfortable at a somewhat lower thermostat setting, conserving heat energy.

With good tight storm windows, the surface temperature of interior windows will be high enough that no condensation will take place until outside temperatures approach 5 to 10 degrees below zero, assuming the indoor temperature is 70°F and relative humidity is 35 percent. The indoor relative humidity may, however, need to be adjusted from time to time with changes in outdoor temperatures.

CONTROLLING MOISTURE WITH MECHANICAL VENTILATION

To avoid excessive accumulation of moisture in the living areas of the home, it is well to remove as much moisture vapor as possible near those points where it enters the home. Ventilation exhaust fans in the bathroom and near the laundry area will remove the largest amounts of moisture that commonly develop. They also control odors.

With good structural ventilation, forced attic ventilation (not to be confused with whole house ventilation) is normally not required. Because of periodic use, the laundry fan can be switched manually on and off. If clothes are hung indoors to dry, the drying area must be well ventilated to avoid excess vapor buildup.

Bathroom, kitchen, and laundry area fans should be vented directly outdoors. Unless equipped with safe, energy-conserving devices, clothes driers should be vented to the outdoors. With good management, considerable heat from clothes driers can be recycled, however, in winter.

Ventilation requirements used by the Federal Housing Authority (FHA) and the Farm and Home Administration (FmHA) should be met by all new construction. These require that:

—bathroom fans have sufficient capacity to provide 8 air changes per hour.

—kitchen fans provide 15 air changes per hour, in space used as kitchen.

—range hood fan capacities be based on 50 cfm per foot of length of hood with a minimum of 40 cfm. All exhaust air should be vented to the outside.

MOISTURE CONTROL WITH VAPOR BARRIERS

Since warm air will hold more moisture than cold air, it, like steam, has pressure, the amount of which varies with the moisture content of the air. During cold weather, vapor pressures inside a home are higher than those on the outside. These tend to force moisture through the walls, from warm inside to cold outside wall members.

If moisture vapor is allowed to penetrate the insulation, the sidewalls and exterior paint can be damaged or the effectiveness of the insulation may be reduced. Excessive moisture in walls of new homes can be prevented by the proper use of vapor barriers and structural ventilation. If necessary, the wall cavities can be vented to let moisture pass through.

Good *vapor barriers* are special materials that prevent water vapor from passing into the insulation. They should always be installed near the warm surface of the room. In residences, this is near the *inside* wall because the winter temperature differential is often 70-80 degrees while summer temperature differentials are seldom over 25 degrees. A ceiling vapor barrier is normally not recommended in electrically heated Missouri homes, provided all attic spaces are structurally ventilated, at least as well as recommended herein. Some are used, however, especially when required by building codes.

Nearly all materials resist vapor movement to some degree. Many water-proof materials are not *vapor-proof*. The relative vapor transmission of a number of different materials is shown in Table 3. The "perm" value represents the ease of vapor movement or transfer from the warm to cold surface. The smaller the numerical value of permeance the better the vapor barrier and the smaller the amount of water vapor that will pass through this material. Materials with values of zero will allow practically no vapor to pass.

Sheet metals, aluminum foil, polyethelene plastic film, glass, some specially-prepared paints, or two coats of aluminum paint on plaster will block nearly all moisture movement, if properly installed or applied and sealed at all joints. One of these materials is depicted in Figure 12. Clear plastic sheets, 6 mil in thickness, are

TABLE 3—WATER VAPOR TRANSMISSION OF CONSTRUCTION MATERIALS*

Material	Permeance** (Perm)
1. Gypsum wall board (0.375 in., plain)	50
2. Mineral wool (3 1/2 in., unprotected)	33
3. Paint—3 coats, styrene-butadiene latex coating, 2 oz/sq. ft.	5.5
4. Concrete block (8 in., cored, limestone aggregate)	2.4
5. Plywood (Douglas fir, interior glue, 0.25 in. thick)	1.9
6. Expanded polystyrene—extruded (1 in.)	1.2
7. Expanded polyurethane (1 in.)	0.4-1.6
8. 15 lb. asphalt felt	1.0
9. Paint—3 coats, exterior paint, white lead and oil on wood siding	0.3-1.0
10. Brick masonry (4 in. thick)	0.8
11. Concrete (8 in., 1:2:4 mix)	0.4
12. Asphalt-saturated and coated vapor barrier paper	0.2-0.3
13. Hot melt asphalt, 3.5 oz/sq. ft.	0.1
14. Polyethylene (6 mil)	0.06
15. Saturated and coated roll roofing	0.05
16. Aluminum foil (1 mil)	0.0
17. Plaster, with two coats of aluminum paint	0.0

*From Reference 1

**The Permeance of a material indicates the relative vapor transfer through that material. The smaller the permeance, the smaller the amount of moisture that will pass through each square foot of surface area. In other words, Items 14, 15, 16, and 17 provide good vapor barriers for home construction.

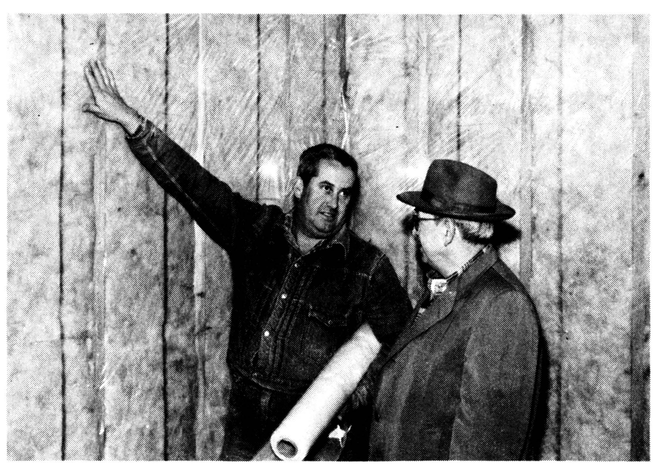


Fig. 12—Clear polyethelene plastic provides good vapor barrier near warm side of wall. Gypsum board or other finish material is easy to apply when full stud width can be seen.

easy to install over insulation. As is true with all vapor barriers, openings around fixtures and any holes made accidentally must be well sealed before wall board is applied. If this is not done, the invisible moisture (vapor) will move into these areas. Sealing holes and cuts with vapor-proof tape, such as vinyl.

Material on the outside of a wall should be more permeable (those with a higher perm value) than the interior wall material. Outer building materials should allow vapor to pass five times more rapidly than materials inside the wall. Then, if any moisture enters the wall, it will move on through it. Foil-enclosed insulation blankets are often used to insulate floors over crawl spaces. In such cases, one side is normally punched with pin holes to allow the vapor to pass through, if any should enter the cavity. This perforated or breather side should be installed on the outer (cold-in-winter) side.

When old homes are remodeled and insulation is blown into the walls, plastic sheet vapor barriers cannot be installed easily. Here, two coats of aluminum paint can be applied to the interior surface of all walls exposed to outside weather. Properly applied, this will provide a good impermeable film. The second coat must be applied in the opposite direction to the first. The second coat then can be covered with the interior decorative finish. The moisture barrier quality of this paint is due to the leafing properties of the aluminum and the sealing characteristics of the varnish content of the paint.

Some latex and emulsion paints may be used as vapor barriers; others may not. Before purchasing any, check with your paint dealer or a reputable manufacturer representative on the vapor-resisting properties of specific paints and the number of coats necessary to do the job.

To prevent vapor from entering insulation under floors that are over crawl spaces (moving up from the underside), cover the ground in crawl spaces under the house with a good vapor barrier. A 6 mil thick polyethelene plastic sheet is most satisfactory.

When constructing concrete floors, place the concrete carefully over a good vapor barrier so the seal at the lap joints will not be broken. The vapor barrier should extend under perimeter insulation.

For termite protection, chemically treat the soil before placement of plastic. Use bricks, smooth block, or smooth rock (not wood) to hold plastic in place (see Fig. 13).

VENTILATION FOR HEAT AND MOISTURE CONTROL

Even though you do not live in the unfinished attic or crawl spaces, the treatment given these areas can have a direct effect upon your comfort. It also affects the life of key structural members, energy use and operating costs.

Crawl spaces under homes without basements must be ventilated to control the upward movement of ground moisture. This is true even when the plastic sheet is laid over the ground surface (as in Figure 13) and the floors are insulated from the ground space.

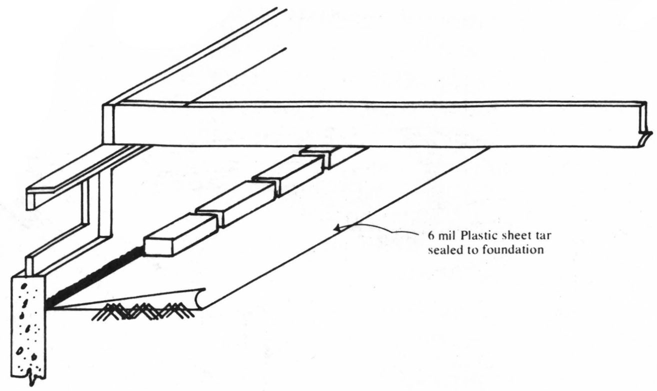


Fig. 13—Control moisture in crawl space of basementless houses by using a vapor barrier over the ground surface.

For crawl spaces where the ground is covered with a good vapor barrier or vapor seal, provide at least 1 sq. ft. of (open space) vent area for each 300 square feet of floor area. This should be provided by at least two, but preferably four, foundation wall vents, similar to that shown in Figure 15.

Attic ventilation is necessary to remove vaporized moisture that moves through the ceiling insulation. Adequate ventilation will keep the attic insulation dry and effective.

Good structural ventilation begins in the planning stage with one-half of the required ventilating space provided at the ridgeline or upper portion of the attic space. The other half is provided by eave or soffit vents. Types of structural ventilating units are shown in Figure 14. The minimum structural ventilation to be provided any home should be no less than the FHA minimum property standards as listed below:

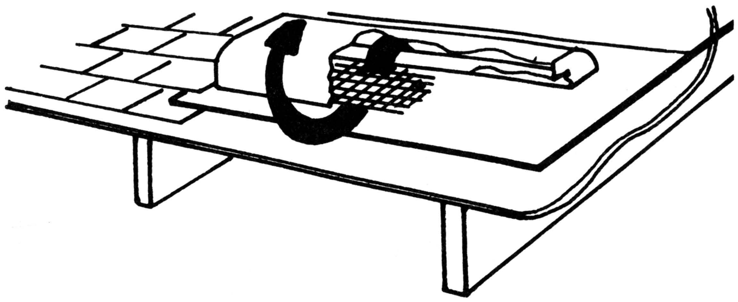
ATTIC VENTILATION

1. Cross-ventilation should be provided for each separate attic space—by vent openings that protect against entrance of rain and snow. For effective air flow, a ridge vent-soffit vent combination is recommended (see Fig. 14). Other combinations can be used as long as net-free air vent space areas are met.
2. With a ceiling vapor barrier, provide 1 sq. ft. of vent opening for each 300 sq. ft. of attic floor space. (This is about 1/2 sq. in. per square foot of attic floor.)

   Without a ceiling vapor barrier, provide 1 sq. ft. of vent opening for each 150 sq. ft. of attic floor space. (This is about 1 sq. in. per square foot of attic floor.)
3. In either case (No. 2 above), place 50% of the net-free vent area high in gables or as ridge vents. Then divide the remaining 50% equally as a continuous soffit vent on either side of the home.

Most openings will or should be screened with 1/4 inch hardware cloth. If mesh openings are smaller, increase vent area proportionately. To avoid reducing net vent area, do not paint screening.

Fig. 14—Roof Vent Options



Roof Vent

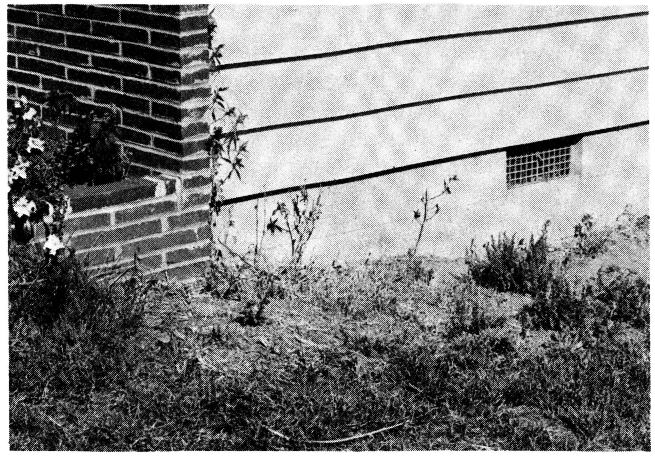
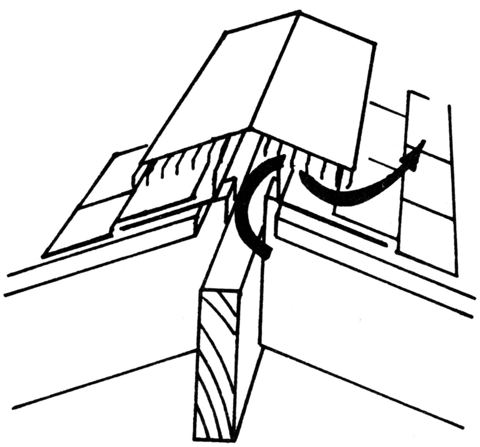


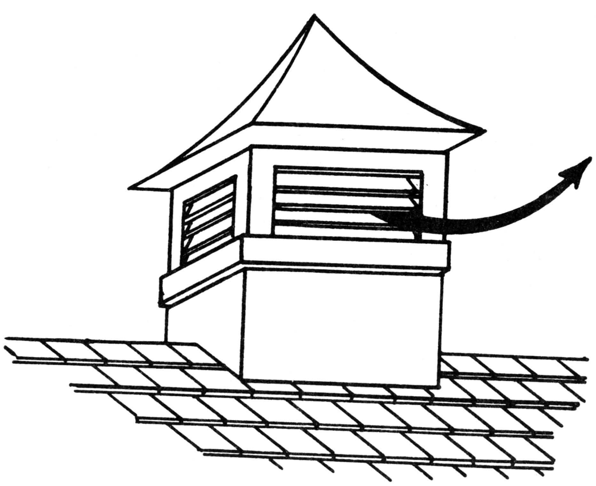
Fig. 15—Screened openings into crawl space under homes, located near each corner and directly under floor joints, allow moisture to escape to the outside air.



Ridge Vent

CRAWL SPACE VENTILATION

1. The earth in any and all crawl spaces should be covered with a 6 mil thick plastic sheet carefully tarred to foundation.
2. At least four vents (two on each side of rectangular areas) should be used for good cross ventilation of the space.
3. Allow at least one square foot of ventilation area (net) for each 800 square feet of space area, assuming a 1/4 inch hardware cloth covering. Divide total into four equal parts.



Cupola Vent

ATTIC VENT POWER FANS

If the recommended structural ventilation requirements (above) are met, or exceeded, there is no need for installation of an electrically powered fan that exhausts air only from the attic. Where natural ventilation cannot possibly be achieved, some existing homes may, however, benefit from power fans as that can reduce excessively high summer attic temperatures (often 135 to 150°F). When such are installed, the fan should have enough capacity to change attic air every 1 to 1.5 minutes. In addition to an attic thermostat (usually set at 95 to 100°F), the fan should, for fire safety, be equipped with an automatic thermal cut-out switch. The net-free inlet area for good fan performance should be about 1.66 sq. ft. for each 1000 cfm of fan capacity.

A humidistat control can aid in control of attic vapor in winter but routine maintenance is a must. The motor manufacturer's maintenance schedule must also be followed. Adequate vent openings must be assured.

WHOLE HOUSE VENTILATION

A large capacity fan appropriately mounted in the ceiling of living quarters can, with proper inlet (normally windows) and outlet vents, cool living quarters and remove excess attic heat, all at one time. Such components, can reduce summer air conditioning costs. IMPORTANT: With such WHOLE HOUSE VENTILATION systems, a well-insulated cover (for horizontally mounted fans) or insulated box (for vertical fan installations) should be installed before cold weather and removed in the spring. For maximum energy conservation, such insulated covers must be well sealed at joints. A switch that can be locked to assure fan operation only when uncovered should be used in such instances. See UMC Guide No. 1706 for more details.

OF SPECIAL NOTE

Every citizen has a responsibility to conserve energy resources. Home planners and builders have a responsibility to design, locate, and construct homes that allow optimum use of electricity for heating and cooling. Good home orientation, proper insulation, and double (or triple) glazing, coupled with proper selection and installation of equipment, will result in significant energy savings and relatively lower utility bills, though unit costs will increase.

TO BE SURE you get what you pay for in your insulation investment contract your job with a local, reliable businessman on the basis of installed performance factors. Your electric power supplier is often as interested in optimum energy utilization and energy management as are you. Consult your supplier for local up-to-date advice on materials and workmanship.

REFERENCES

1. ASHRAE Handbook—1977 Fundamentals, American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 345 East 47th Street, New York, New York.
2. Research Series Bulletin No. 106. 1948. Engineering Experiment Station, Purdue University, Lafayette, Indiana.
3. Minimum Property Standards for One and Two Family Dwellings, F.H.A. 4900.1. 1973. Revised March, 1976. U.S. Government Printing Office, Washington, D.C.
4. Barr, H. J. and L. L. Sammett. 1950. Farm Structures, John Wiley & Sons, New York, New York. Pages 157-58.
5. Felicone, F., et al. 1959. Paints as a Vapor Barrier on Interior Wall Surface, Circ. 785, National Paint, Varnish and Lacquer Association, Inc., Washington, D.C. December.

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