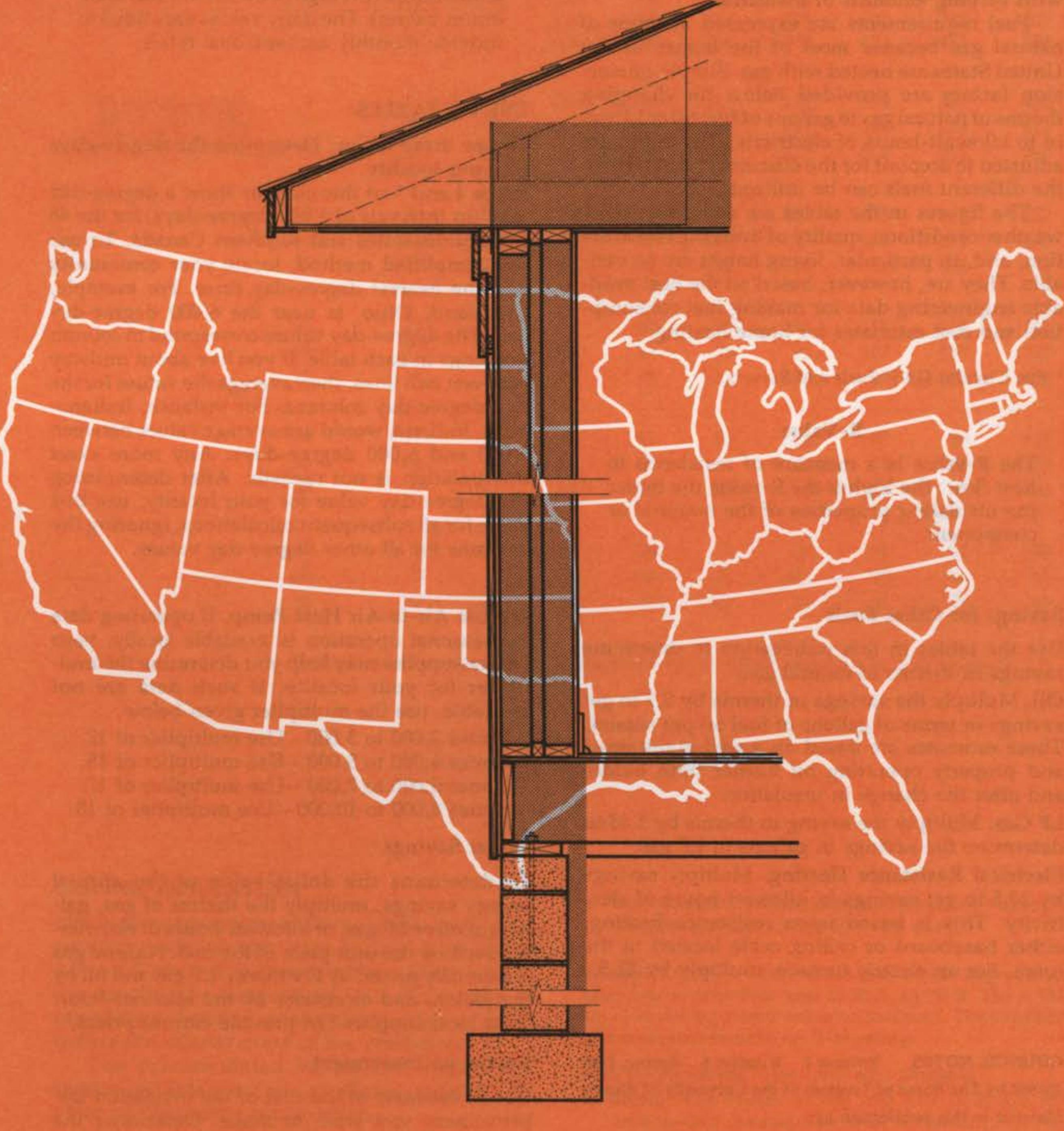
University of Illinois at Urbana-Champaign
Small Homes Council-Building Research Council

COUNCIL NOTES



A1.62 SAVINGS
by Insulating Ceilings, Walls, and Foundations

Savings by Insulating Ceilings, Walls, and Foundations   A1.62   Volume 4   Number 4   Spring, 1981   Twenty five Cents

This publication provides data for estimating the energy that can be saved by the insulation of various house components, such as ceilings, walls, and foundations.

The tables give estimates of the amount of natural gas that must be purchased and consumed to offset the heat loss from each house component with varying amounts of insulation.

Fuel requirements are expressed in terms of natural gas because most of the homes in the United States are heated with gas. Simple conversion factors are provided below for changing therms of natural gas to gallons of fuel oil or LP gas or to kilowatt-hours of electricity. The tables are adjusted to account for the efficiency* with which the different fuels can be utilized.

The figures in the tables are estimates, since weather conditions, quality of building construction, and, in particular, living habits are so variable. They are, however, based on the best available engineering data for making fuel consumption and cost estimates for home heating.

* See Circular G3.5, *Fuels and Burners*.

R-Value

The R-value is a measure of resistance to heat flow; the higher the R-value the better the insulating properties of the material or component.

Degree-Days

The degree-day is a convenient measure for estimating the heating demand for a building. For any given day, the number of degree-days for that day is given by the difference between 65°F and the mean daily temperature (average of minimum and maximum values). The daily values are added to provide monthly and seasonal totals.

USE OF TABLES

To use these tables: **Determine the degree-days for your locality**.

Pages 4 and 5 of this circular show a degree-day map (in intervals of 1,000 degree-days) for the 48 contiguous states and southern Canada. To use this simplified method, locate your community and the nearest degree-day lines. For example, Cleveland, Ohio, is near the 6,000 degree-day line. The degree-day values correspond to column headings in each table. If you live about midway between two lines, then average the values for the two degree-day columns. For instance, Indianapolis, Indiana, would use average values between 5,000 and 6,000 degree-days. Any more exact interpolation is not realistic. After determining the degree-day value for your locality, use this value for all subsequent calculations, ignoring the columns for all other degree-day values.

Savings for Other Fuels

Use the tables in this publication to determine savings in therms of natural gas.

Oil. Multiply the savings in therms by 0.7 to get savings in terms of gallons of fuel oil per season. These estimates are based on a well-maintained and properly operating oil burner both **before** and **after** the change in insulation.

LP Gas. Multiply the saving in therms by 1.08 to determine the savings in gallons of LP gas.

Electrical Resistance Heating. Multiply savings by 20.5 to get savings in kilowatt-hours of electricity. This is based upon resistance heating, either baseboard or ceiling cable located in the room. For an electric furnace, multiply by 21.5.

Electric Air-to-Air Heat Pump. If operating data for seasonal operation is available locally, your power supplier may help you determine the multiplier for your locality. If such data are not available, use the multiplier given below.

Zones 2,000 to 3,000 - Use multiplier of 12.
Zones 4,000 to 5,000 - Use multiplier of 15.
Zones 6,000 to 7,000 - Use multiplier of 17.
Zones 8,000 to 10,000 - Use multiplier of 18.

Dollar Savings

To determine the dollar value of the annual energy savings, multiply the therms of gas, gallons of oil or LP gas, or kilowatt-hours of electricity saved by the unit price of the fuel. Natural gas is normally priced by the therm, LP gas and oil by the gallon, and electricity by the kilowatt-hour. Your local supplier can provide current prices.

Return on Investment

Get an estimate of the cost of the insulation improvement you wish to make. Determine the annual dollar savings, as above. Divide the total cost of the improvements into the annual dollar savings, and multiply by 100 to get percent return on investment.

Example. Insulation which costs $325 to install will save $62.50 in fuel each year. The return on investment is $62.50/$325 × 100 = 19.2%.

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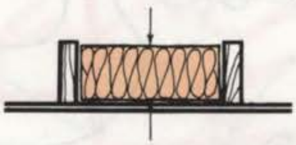
TABLE 1. CEILING INSULATION

(therms of natural gas burned per season to replace heat lost through 1,000 sq. ft. of ceiling)



R-value of insulation in ceiling	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
0	192	297	408	519	631	740	850	964	1076
1	144	223	306	389	474	555	637	723	807
3	96	148	204	260	316	370	425	482	538
5	72	111	153	195	237	278	319	362	404
7	52	83	115	147	179	212	245	278	311
9	43	69	96	123	149	177	204	231	260
11	37	59	82	105	128	151	175	198	222
13	33	52	72	92	112	133	153	174	195
15	29	46	64	82	100	118	136	154	173
17	23	38	54	69	85	102	118	134	151
19	21	35	49	63	78	92	107	122	137
21	19	32	45	58	71	85	98	111	126
24	17	28	40	51	63	75	87	99	112
30	14	23	33	42	52	62	71	81	91
38	9	16	23	30	38	45	52	60	68
44	8	14	20	26	33	39	45	52	59
50	7	12	18	23	29	35	40	46	52
56	6	11	16	21	26	31	36	42	47

Note: Shaded portions of the table show values which may not be cost effective.

CEILING INSULATION

The R-value for commercially available ceiling insulation materials may vary widely, from about 2.0 to 4.0 per inch depending upon the material, the density, the temperature, and the quality of installation. Settling or shrinking may, in time, reduce the effectiveness of the insulation.

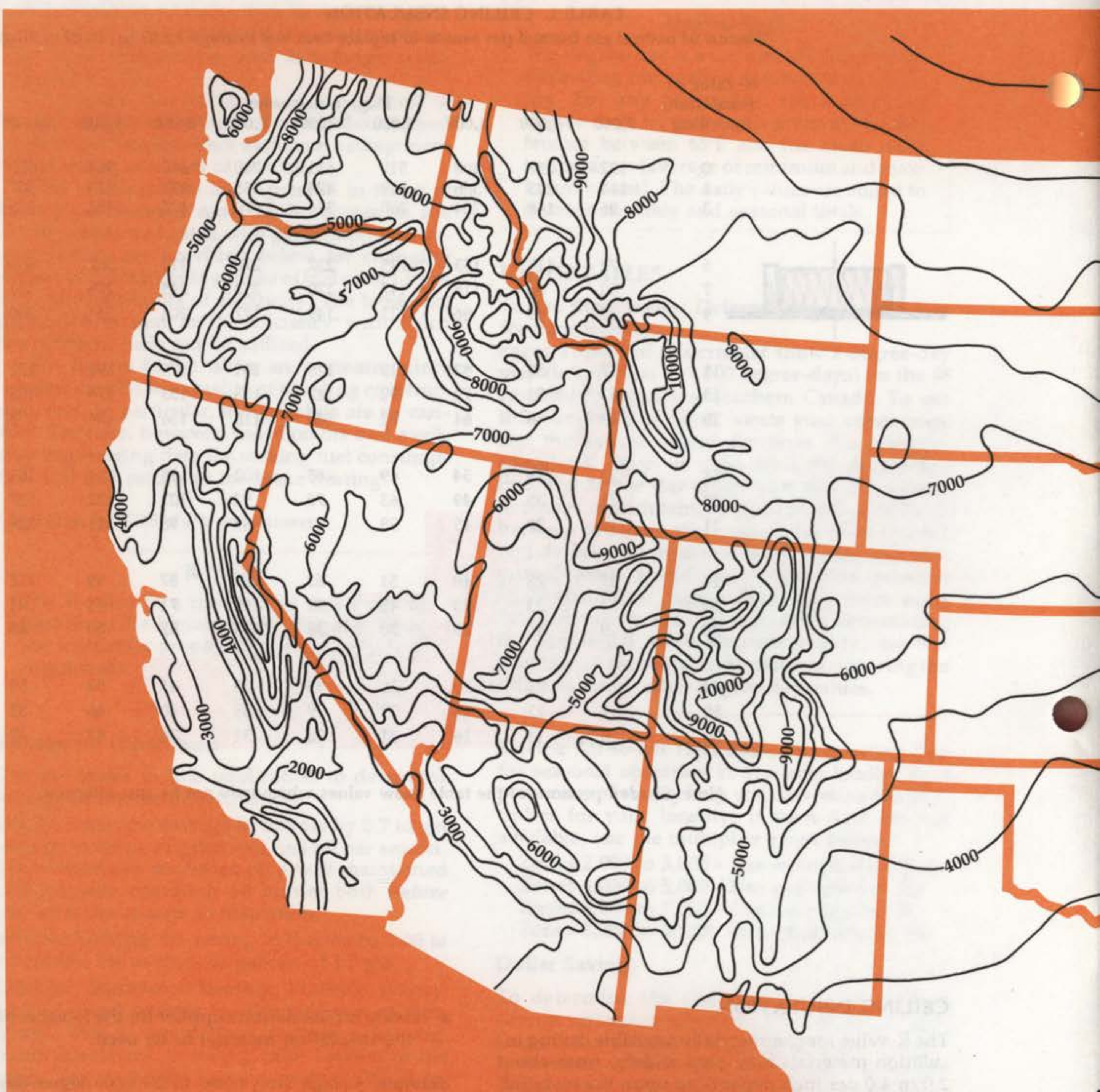
The pre-calculated values for **therms per season** in Table 1 include an allowance for the R-value of the ceiling construction.

- If there is insulation in your attic now, you may use the following figures to approximate the R-value of the existing insulation: vermiculite – R-2 per inch of thickness; mineral wool, glass fiber, cellulose – R-3 per inch of thickness. By interpolation, use the R-value in Table 1.
- Ask your insulation supplier for the R-value of the insulation material to be used.

Example. A single-story house in the 4,000 degree-day zone has an attic floor area of 30 ft. by 50 ft. The 1,500 sq. ft. of ceiling area is not now insulated. The supplier offers insulation with an R-19 rating.

Fuel Requirement before and after changes.

1. **Before:** The values in the first line (R-0) are for ceiling-attic construction with no insulation. For each 1,000 sq. ft. the therms required are 408.
2. **After:** The values in the line for R-19 show 49 therms for each 1,000 sq. ft. of ceiling area.
3 **Therm Savings:** For each 1,000 sq. ft., the savings will be 408 − 49 = 359 therms per season.
4. **Adjustment for Area:** 359 × 1.5 = 538 therms for 1,500 sq. ft.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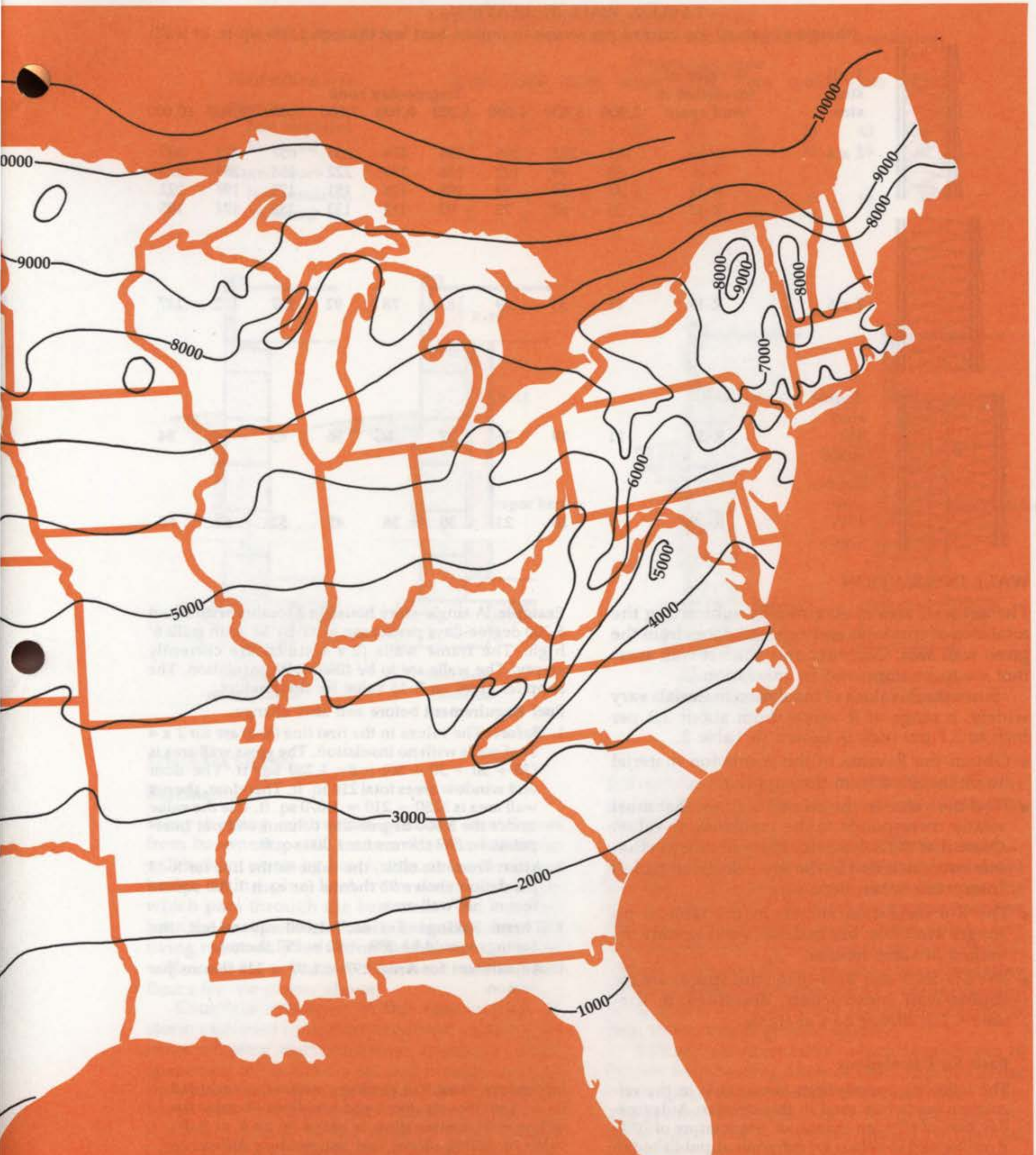
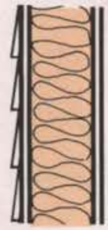
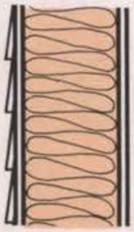
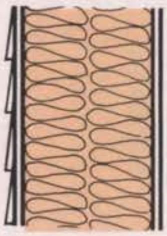


HEATING DEGREE-DAYS
65°F. base
Redrawn from The National Atlas of the United States of America, 1970

TABLE 2. WALL INSULATION
(therms of natural gas burned per season to replace heat lost through 1,000 sq. ft. of wall)







Wall stud size	R-value of insulation in stud space	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
2 x 4	none	144	223	306	389	474	555	637	723	807
	R-6	58	89	122	156	189	222	255	289	323
	R-11	37	59	82	105	128	151	175	198	222
	R-13	33	52	72	92	112	133	153	174	195
2 x 6	R-19	21	35	49	63	78	92	107	122	137
double stud 8½" space	R-30	11	19	28	37	46	56	65	74	84
double stud 10½" space	R-38	9	16	23	30	38	45	52	60	68

WALL INSULATION

The **net wall area** is obtained by subtracting the total area of windows and exposed doors from the **gross wall area**. Consider only the net wall areas that are to be improved by insulation.

Since the R-values of insulation materials vary widely, a range of R-values from about 3.2 per inch to 3.7 per inch is shown in Table 2.

- Obtain the R-value of the insulation material to be installed from the supplier.
- Find the value in the second column that most nearly corresponds to the insulation R-value. (Note that the R-value for the wall construction has been included in the pre-calculated table.) Interpolate when necessary.
- The R-6 insulation shown in the table is no longer available, but may be found already installed in some houses.
- The 8½-inch and 10½-inch stud spaces are for **double-wall** construction, described in Circular C2.3, *Illinois Lo-Cal House*.

Example. A single-story house in a locality with about 5,200 degree-days per season is 30′ by 50′ with walls 8′ high. The frame walls (2 x 4 studs) are currently empty. The walls are to be filled with insulation. The supplier gives an R-13 value for the product.

Fuel Requirement before and after change.

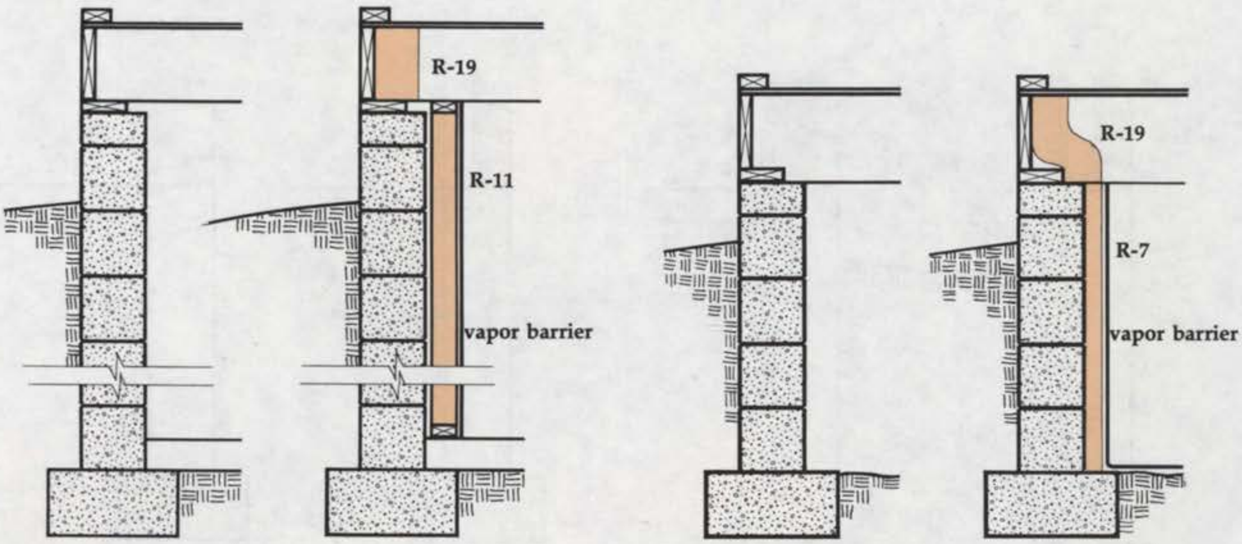
1. **Before:** The values in the first line (R-0) are for 2 x 4 stud walls with no insulation. The gross wall area is (30 + 50 + 30 + 50) × 8= 1,280 sq. ft. The door and window areas total 210 sq. ft. Therefore, the net wall area is 1280 − 210 = 1,070 sq. ft. Use the value under the 5,000 degree-day column without interpolation; 389 therms for 1,000 sq. ft.
2. **After:** From the table, the value in the line for R-13 insulation shows 92 therms for each 1,000 square feet of net wall area.
3. **Therm Savings:** For each 1,000 square feet, the savings would be 389 − 92 = 297 therms.
4. **Adjustment for Area:** 297 × 1.07 = 318 therms per season.

Basis for Calculations

The following assumptions were made in the calculation procedure used in this circular: A degree-day base of 65°F; an indoor-air temperature of 70°F; R-values and U-values for materials as published in ASHRAE tables; for natural gas, furnace and boiler efficiency of 70%; for fuel oil, calorific value of 140,000 Btu per gallon and efficiency of 70%; for electrical resistance heating, thermal value of 3412 Btu per kWh and efficiency of 100%; for electrical heat pump heating, performance as indicated; infiltration, based on crackage method, is included in the heat loss for doors and windows; R-value for ceiling-roof combination is based on an R of 3 (R-value of ceiling alone) and temperature difference taken from indoor to outdoor air; slab floor design heat loss data from Small Homes Council data; and, finally, the modification in the "24" of the basic equation as in *Estimating Energy Requirements for Residential Heating*, by Warren S. Harris and Calvin H. Fitch, ASHRAE Journal, October, 1965.

TABLE 3. FOUNDATION INSULATION
(therms of natural gas burned per season to replace heat lost through 10 ft. of foundation)

Foundation type	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Basement									
Not insulated	9	13	18	23	28	33	38	43	48
Insulated	3	5	7	9	11	13	16	18	20
Crawl space									
Not insulated	4	6	8	10	12	14	16	18	20
Insulated	2	2	3	4	5	6	7	8	9



basement no insulation — basement insulated — crawl space no insulation — crawl space insulated

FOUNDATIONS

Basements

Many heating contractors overlook heat losses from basements, and assume that the basement will be kept warm by heat lost from the furnace or boiler casing plus heat from ducts and pipes which pass through the basement. The heat lost from the basement is as costly as heat lost from the living room. Any reduction in basement heat loss will result in a warmer basement and warmer floors for the rooms above.

Complete insulation in this case consists of: storm sash over basement windows, caulking beween sill plate and foundation, insulation of the space next to the band joist, and insulation of the basement wall. The calculations in Table 3 are based upon insulating the basement walls with R-4 foam plastic board covered with ½-inch gypsum drywall, the band joist with R-19 batts, and double glazing on basement windows.

Crawl Spaces

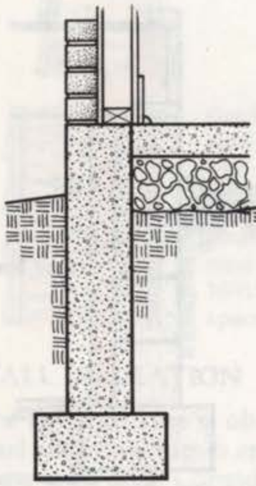
All crawl spaces should be dry and well above the water table for the site. The ground surface should be covered with a layer of polyethylene plastic to prevent the evaporation of water vapor from the ground into the crawl space and eventually into the house above.

One alternative that is frequently recommended in the case of houses with **electrical resistance heating** is to place insulating batts between the floor joists (as much as R-19) to prevent heat loss from the heated space to the crawl space. Any water pipes in the crawl space (both hot and cold) should be located above the insulation. Insulating the floor over a crawl space may increase cooling costs, since it prevents the radiation of summer heat to the cooler ground surface.

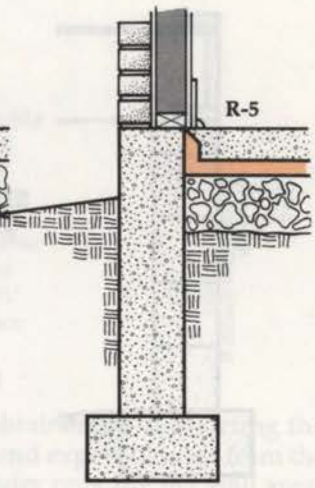
The second alternative, which is preferred in houses with heating ducts or heating pipes in the crawl space, is to insulate the crawl space walls and to close the foundation vents. In this case, the crawl space will be partially heated by the heat radiating from ducts and pipes. Complete insulation of the crawl space consists of: closing of all vent openings in the foundation walls, covering of the vent openings with insulating inserts, caulking between the sill plate and the top of the foundation, insulation of the band joist (R-19), and insulation of the crawl space walls (R-10).

TABLE 4. FOUNDATION INSULATION
(therms of natural gas burned per season to replace heat lost through 10 ft. of foundation)

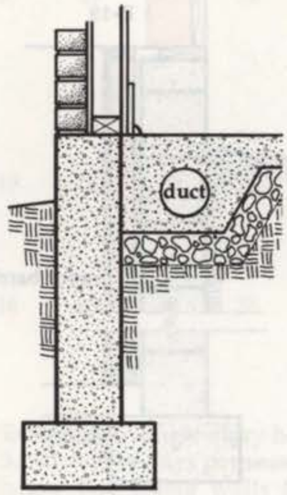
Foundation type	Degree-day zone 2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
Slab-on-ground									
Unheated edge									
Not insulated	5	7	10	13	15	18	20	23	26
Insulated	3	5	6	8	10	11	13	15	17
Heated edge									
Not insulated	8	13	17	22	27	31	36	41	45
Insulated	5	7	10	13	16	19	21	24	27



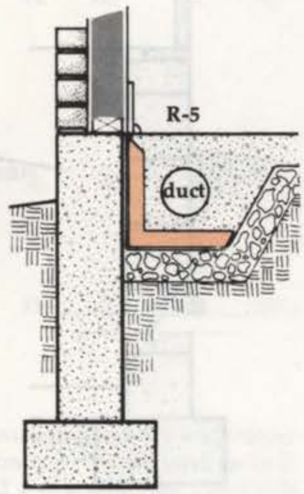
slab-unheated edge
no insulation



slab-unheated edge
insulated



slab-heated edge
no insulation



slab-heated edge
insulated

Slab-on-Ground

Concrete is a good conductor of heat. In the case of a concrete floor slab, the heat flow from the house to and out the edge of the slab can be retarded by placing a thermal break between the concrete slab and the outdoor air. In the case of new construction, the recommended procedure is to place a water-resistant insulation (such as extruded polystyrene foam) between the slab and the foundation and extending downward at least 24″ or extending through the slab and back beneath it a similar distance.

For existing construction, a recommended retrofit insulation consists of a 1½-inch sheet of extruded polystyrene foam installed on the outside of the concrete foundation from the plate to at least 24″ below grade. The foam board should be protected with cement-asbestos board, pressure-treated plywood, or metal. A sheet metal flashing should extend from behind the siding over the insulation to shed water.

Some slab-on-ground houses have a warm air heat duct extending completely around the outside edge of the slab. There is more heat loss from this heated edge system than from a conventional system having ducts leading from the furnace directly to the registers, although the floor is warmer and more comfortable.

Example: A crawl space house located in a 7,000 degree-day zone had dimensions of 25′ by 40′. The crawl space is totally enclosed and the earth surface is covered with a polyethylene sheet. What will be the energy savings if the uninsulated crawl space is completely insulated?

Fuel Requirement before and after change.

1. **Before:** In a 7,000 degree-day zone, the value for a uninsulated crawl space is 14 therms per season for each 10 linear feet of perimeter.
2. **After:** The values for an insulated crawl space in the 7,000 degree-day zone is 6 therms per season for each 10 linear feet of perimeter.
3. **Therm Savings:** For each 10 linear feet of perimeter, the savings will be 14 − 6= 8 therms.
4. **Adjustment for Area:** The perimeter of the crawl space is (25 + 40 + 25 + 40) = 130 linear feet. 8 × 13 = 104 therms per season saved.

In addition to the energy savings, the crawl space will be warmer, as will the floor surface of the rooms over the crawl space, and comfort conditions in the house will be improved.