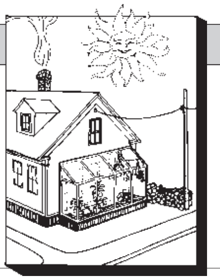


Foundation Insulation

Part I

by Alex Wilson

It is estimated that only about 5 percent of all the buildings in America have insulated foundations. Collectively, the heat lost through basement walls, concrete slabs and crawl spaces from our 100 million or so residential buildings represents half a quadrillion Btu — roughly half the current nuclear-generating capacity in the U.S.

When the notion of energy-efficient construction first caught on in the early 70s, an interesting "insulation evolution" began. First we addressed ceilings—they were easy. We could simply add another layer of fiberglass batts or blow in the stuff.

Then came the walls. Two-by-sixes weren't that much more expensive than two-by-fours, and we could achieve a much higher R-value. Two-by-eights allowed for even more, as did the addition of rigid insulation.

With ceilings and walls taken care of, we turned our attention to windows, adding thermopane glass, heat-reflective glazings, triple- and quad-pane windows (sometimes with inner layers of plastic-film glazing), and even moveable insulation systems to cover our windows at night.

Then we discovered that infiltration was the biggest heat-loss culprit. Enter tighter air/vapor barriers, caulking, "house doctor" services, blower doors, "Tyvek" and the like. Our houses became so tight that we began to worry about indoor air quality.

With the rest of our house so tightly sealed, foundations—which had been of little concern when the other components of our house were so poorly insulated—became a major contributor to heat loss.

So we have begun to insulate foundations in new construction, but we're still playing catch-up. Even in modern "energy-efficient" houses, foundations are seldom insulated to the same extent as the rest of the house.

Below-Grade Heat Flow

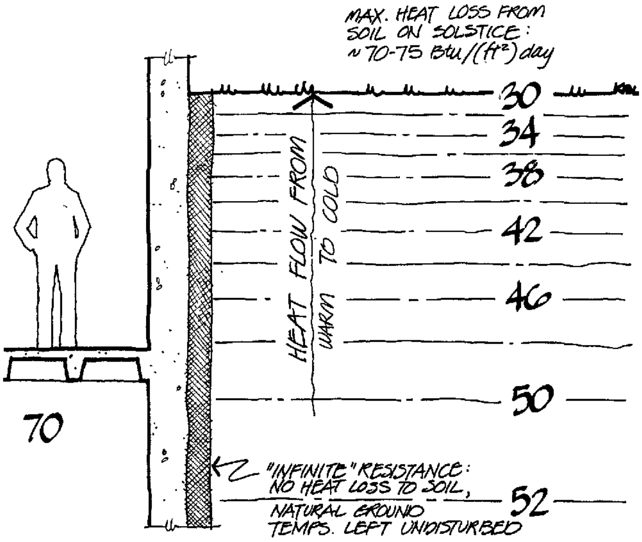
One reason foundation insulation hasn't gotten the attention it deserves is the confusion over what happens with below-grade heat flow. Heat loss from foundations is extremely complex.

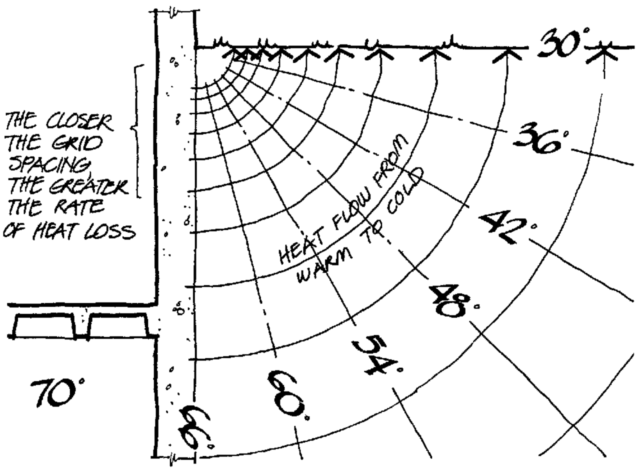
Instead of flowing to the outside air, heat is lost to the ground, where temperatures do not fluctuate as much as in the air. And the deeper you go, the less they fluctuate. In fact, at about 10 feet deep, temperatures are constant year-round, while the temperature near the surface is much closer to ambient air temperatures.

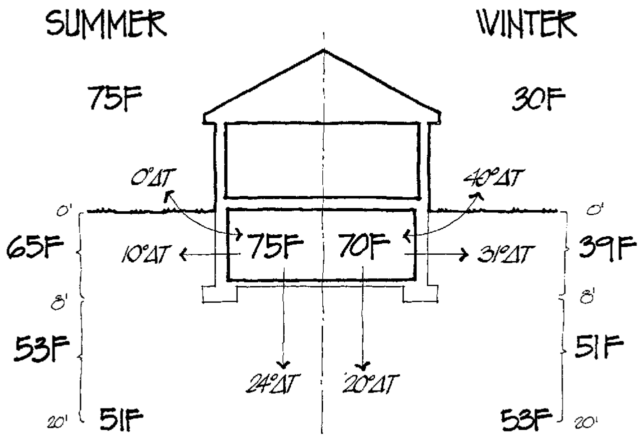
In addition, ground-temperature cycles lag behind ambient air temperatures because of the earth's tremendous heat capacity. This thermal lag adds to the complexity of calculating foundation heat loss.

When a house is built on a piece of ground, the thermal characteristics of the ground are changed dramatically. If there is a heated basement, the foundation walls will be relatively constant in temperature, but they will lose more heat near the top because ground near the surface cools off more.

In the winter, the soil provides some effective R-value for the foundation. The deeper the foundation lies beneath the surface, the greater the R-value.







Drawings by Ken Labs

Adding insulation to the foundation wall, of course, will decrease heat lost from the foundation. But if the insulation is tapered—with more at the top and less deeper down—the insulation is more cost effective. (Ill discuss this aspect in greater detail next month.)

We have a different situation with heat loss from the basement floor. Heat sinks down into the earth—not up toward the surface of the ground. At about 10 feet down, the earth in the Northeast stays a relatively constant 45 to 50 F, so the heat loss will be relatively even and constant year-round.

With slab-on-grade foundations, the perimeter loses heat to the surface, while the center loses heat down into the ground. Adding perimeter insulation drastically cuts down on the edge losses, while insulation under the slab reduces the downward flow of heat.

As if the situation isn't complex enough already, we need to consider the soil type as well. Some soils are more conductive than others—in other words, they allow heat to flow through them more readily.

Soil moisture and groundwater also play an important role. If groundwater reaches the underside of a slab, for example, heat loss from that slab will be much greater.

Calculating Foundation Heat Loss

There are a number of ways—accurate and inaccurate, simple and complex—to determine the heat loss of a foundation.

The most common way to calculate heat loss from basement walls—the most complex situation—is to mathematically divide the wall into segments (usually one-foot vertical increments), calculate the heat loss for each, then add them together. In this way, the greater R-value of soil at greater depths is taken into account.

To be as accurate as possible, a formula should factor in soil conductivity; infiltration through pipe penetrations, ventilation windows and the like; and the fact that some portion of the foundation wall is usually above grade. I do not know of any formula that includes infiltration, however.

With slabs, everything but the perimeter usually is ignored. Basement floors, therefore, typically are omitted from calculations. The reasoning is that the downward heat flow from slabs reaches a steady state with the constant earth temperature, and not that much heat is lost. (I'll explain why it might be a good idea to insulate under slabs anyway in next month's column.)

Another consideration to take into account when calculating foundation heat loss is what the numbers will be used for.

If you want to determine the maximum output needs for a furnace on the coldest day of the year *(i.e.,* the design temperature), you want the answer in Btus per hour for those conditions.

If you are interested in figuring the heat load per month or year, you need the answer in Btus per month or year.

With above-grade heat-loss calculations, you can easily convert from hourly to monthly to yearly values simply by factoring in the number of degree-days. Below-grade calculations don't work that way, however, because of thermal lag and the fact that soil temperatures are not directly related to air temperatures.

As a result, converting from one type of answer to another is quite complicated.

With all the factors to consider when calculating foundation heat loss, the use of computers is probably the only way to quickly obtain reliable numbers. That's fine for engineers and energy-audit specialists, of course. If most of us ever do anything with foundation heat-loss calculations, I suspect we will want quick hand-calculation approximations.

The goal for hand calculations is to select the simplest formula that will most closely approximate the complex heat flows of foundations. Three of these—two for determining basement heat loss and one for slab-on-grade heat loss—are presented below. (All temperatures are in degrees Fahrenheit.)

1. $$Q = \frac{(Ti - To)D}{Rwall + D/k} \times P$$

Q = heat loss in Btu/hour
Ti = indoor temperature (F)
To = outdoor temperature (F)
Rwall = R-value of basement wall (1/Btu/sq. ft. per hour)
k = soil conductivity in Btu/ft. per hour (use k of 1.0 for wet soil; 0.6 for dry soil, and 0.8 as a representative value)
D = depth of basement in feet
P = wall perimeter in feet

The above formula, a slight adaptation of the current ASHRAE method, gives the hourly heat loss of a basement.

2. $$Qbasement = 256 \times \frac{P}{Rwall + 8} \times DD$$

3. $$Qslab = 100 \times \frac{P}{Rperim + 5} \times DD$$

Q = heat loss in Btu/year
P = perimeter of basement or slab in feet
Rwall = R-value of basement wall
Rperim = R-value of perimeter insulation
DD = number of degree-days per year
(The numbers 256 and 100 give the answer in Btu per year.)

The last two formulas are simplifications of the ASHRAE method developed by the Los Alamos National Laboratory. Formula 2 assumes an eight-foot-deep basement. There are less exact formulas that can give an estimate of annual heat loss.

To see how compatible formulas 1 and 2 are, I analyzed a standard 32' x 32' house in Portland, Maine, with R-10 foundation insulation. Through a rather complex procedure discussed by Ken Labs in the January 1985 issue of *Solar Age*, I was able to determine the annual heat loss from formula 1.

My answers came out to be 9.6 million Btu per year from formula 1 and 14.5 million Btu per year from formula 2 —not quite as close as I would hope, but not too bad.

Next month, I'll bring this information down to a practical level with recommendations on how much foundation insulation to use, where to use it and why to use it. The following month, I will address retrofit insulation—a real challenge! ■

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