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Until the last decade or so house basements were used largely as storage and work areas that required little in the way of deliberately supplied heat. Casing losses from warm air furnaces or boilers and heat from ducts and pipes supplied all that was required.

When basements are used as living accommodation, however, the heating requirements become of more concern, at least for that part of the basement space so used. The introduction of electrical heating equipment, which has no casing losses, has made it necessary to have reasonably reliable methods of calculating heat losses from the basement so that the correct size of unit can be selected. With all methods of heating, considerations of economy dictate that heat losses be calculated and insulation provided where necessary.

Heat losses through the portion of the basement wall above grade can be calculated in the same manner as those for any other above-grade wall, taking into account both conduction and air leakage; although special note should be taken of the air leakage between the basement wall and the sill plate. Below grade it is normal to adopt a uniform heat loss per square foot of wall or floor, based on empirical values. Such values give no indication of the greater heat loss through the wall near the ground surface relative to that through the lower parts. Thus they cannot be used to estimate the depth below grade to which it is economical to carry insulation.

It has been shown (1) that heat loss through the soil surrounding a house basement can be calculated on the basis of steady-state heat flow round concentric circular paths centred on the intersection of the ground surface and the basement wall. For the floor these paths are continued around circular arcs centred on the intersection of the basement floor and wall (Figure 1).

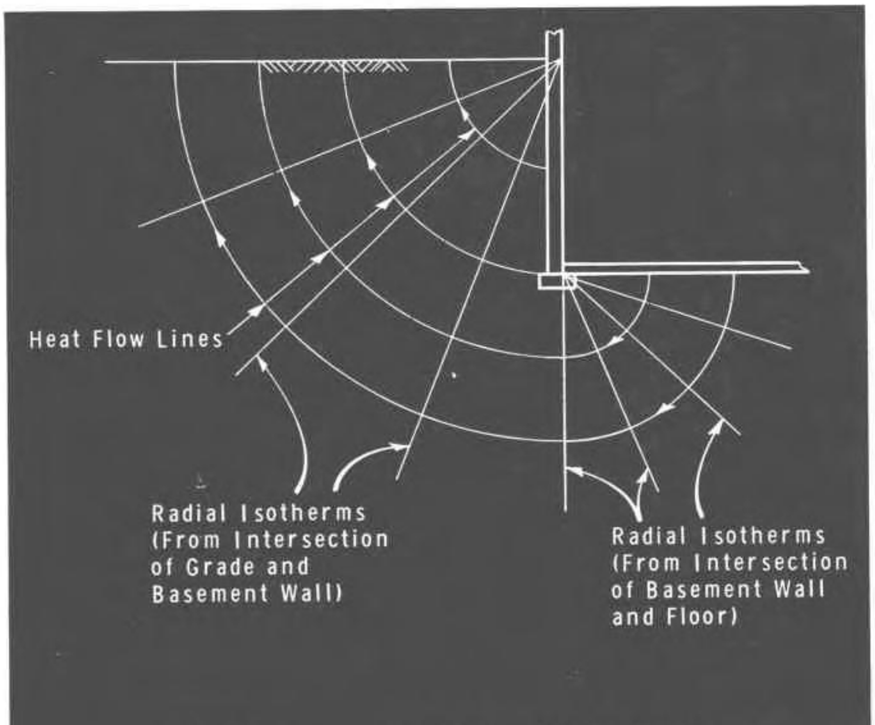


FIGURE 1 HEAT FLOW FROM BASEMENT

**Walls Below Grade**

The heat loss per square foot for a 1 F degree temperature difference between the basement temperature and the external temperature is given in Table I for uninsulated concrete walls and for those to which 1, 2 or 3 in. of insulation have been added. An average value of 0.8 Btu/(hr) (ft) (°F) has been assumed for the conductivity of soil, and insulation is assumed to have a coefficient of conductivity of 0.24 Btu/(hr)(ft2 )(°F/in). It should be noted in passing that it is the convention to quote the conductivity of soils for 1-ft thickness and not for 1-in. thickness as for other building materials.

**Basement Floors**

It is possible to calculate the heat loss through the basement floor for each square foot in the same way as the heat loss for the wall, using longer heat flow paths around the arcs of two circles (see Figure 1). It may be seen from Table I, however, that the heat loss from the 7th foot of the uninsulated basement wall is only a small fraction of the total loss through the wall; thus it can readily be appreciated that (with the much longer heat flow path) the loss through each square foot of basement floor rapidly becomes a negligible part of the total basement heat loss. It is reasonable, therefore, to take an average value for the loss through the basement floor. This value can be multiplied by the floor area to give the total floor heat loss.

The average rate of heat loss through the floor may be taken as equal to that from a point located one quarter of the basement width from the side wall. The path length from this point varies with both depth of basement below grade and width of basement. Shallow narrow basements will have higher heat loss per square foot than will deep wide basements. Typical values are given in Table II.

The heat loss from the below-grade portion of the basement per F degree temperature difference can be estimated using the figures given in Tables I and II. For the wall, the values for heat loss through each square foot are selected from Table I, added together, and the total multiplied by the perimeter of the house. For the floor, the average heat loss per square foot is estimated from Table II and multiplied by the floor area. The resulting two values may then be added together and multiplied by the appropriate design temperature difference to give the maximum rate of heat loss from that portion of the basement below grade.

### Design Temperatures

Selecting the appropriate design temperature difference poses something of a problem. Although the internal design temperature is given by the air temperature in the basement, none of the usual external design air temperatures are applicable because of the heat capacity of the soil mass. On the other hand, it can be shown that the ground surface temperature will fluctuate about a mean value ($T_m$) by an amplitude A, which will vary with geographic location and surface cover. Thus suitable external design temperature will be given by subtracting A for the location from the mean annual air temperature $T_a$ which is usually 4 to 6 F deg colder than $T_m$. Table III gives values of $T_a$, $T_m$ and A and of the external design temperature ($T_a$ —A) for various locations in Canada under natural snow conditions.

Values for $T_a$ can be obtained from the meteorological records, and for A can be estimated from Table III and the map given in Figure 2. This map is part of one prepared by Jen-Hu Chang (2) giving annual ranges in ground temperature at a depth of 10 cm (4 in.).

### Below-grade Heat Loss in Relation to Total House Loss

The fraction of total heat loss represented by heat loss below grade will vary with the design of the house. As an indication of what it might be, heat losses both above and below grade are given in Table IV for a typical bungalow of about 1050 sq ft in plan area.

The walls are stud frame with brick veneer and have 3 in. of mineral wool batt insulation, as does the ceiling; approximately 2 ft-3 in. of basement wall is exposed above grade. For purposes of comparison with an uninsulated basement, the effect of eliminating air leakage between the concrete

**TABLE I**

**HEAT LOSS BELOW GRADE: Btu/(hr) (°F) (ft²)**
Insulation with k = 0.24 Btu/(hr) (ft²) (°F/in)
= 0.02 Btu/(hr) (ft) (°F)
Soil k = 0.8 Btu/(hr) (ft) (°F)

| Depth (ft) | Path Length through Soil (ft) | Heat Loss: Uninsulated | 1-in. Insulation | 2-in. Insulation | 3-in. Insulation |
|---|---|---|---|---|---|
| 0-1 (1st) | 0.68 | 0.410 | 0.152 | 0.093 | 0.067 |
| 1-2 (2nd) | 2.27 | 0.222 | 0.116 | 0.079 | 0.059 |
| 2-3 (3rd) | 3.88 | 0.155 | 0.094 | 0.068 | 0.053 |
| 3-4 (4th) | 5.52 | 0.119 | 0.079 | 0.060 | 0.048 |
| 4-5 (5th) | 7.05 | 0.096 | 0.069 | 0.053 | 0.044 |
| 5-6 (6th) | 8.65 | 0.079 | 0.060 | 0.048 | 0.040 |
| 6-7 (7th) | 10.28 | 0.069 | 0.054 | 0.044 | 0.037 |

**TABLE II**
**MEAN BASEMENT FLOOR HEAT LOSS: Btu/(hr) (°F) (ft²)**

| Depth of Foundation Wall below Grade (ft) | Width of House: 20 (ft) | 24 (ft) | 28 (ft) | 32 (ft) |
|---|---|---|---|---|
| 5 | 0.032 | 0.029 | 0.026 | 0.023 |
| 6 | 0.030 | 0.027 | 0.025 | 0.022 |
| 7 | 0.029 | 0.026 | 0.023 | 0.021 |

**TABLE III**
**EXTERNAL DESIGN TEMPERATURES**

| Place | $T_a$ (°F) | $T_m$ (°F) | A (°F) | $T_a$-A (°F) |
|---|---|---|---|---|
| Swift Current, Sask. | 38.5 | 44 | 26 | 12.5 |
| Guelph, Ont. | 44.6 | 48 | 22 | 22.6 |
| Ottawa, Ont. | 42.0 | 48 | 21 | 21.0 |
| Toronto, Ont. | 47.7 | 51 | 23 | 24.7 |
| Ste. Anne de la Pocatière, Qué. | 39.5 | 44 | 20 | 19.5 |
| Fredericton, N.B. | 41.6 | 46 | 22 | 19.6 |
| Charlottetown, P.E.I. | 43.1 | 45 | 16 | 27.1 |
| St. John's, Nfld. | 40.5 | 44 | 15 | 25.5 |
| Saskatoon, Sask. | 35.7 | 42 | 22 | 13.7 |

**HEAT LOSS CALCULATION**
(for portion of basement below grade)

Consider a basement 28 ft wide by 30 ft long, sunk 6 ft below grade, with 2-in. insulation applied to the top 2 ft of wall below grade. Assume an internal air temperature of 70°F and an external design temperature ($T_a$ –A) of 20°F.

**Wall** (Using Table I):

1st ft below grade .......... 0.093
2nd ft below grade .......... 0.079
3rd ft below grade .......... 0.155
4th ft below grade .......... 0.119
5th ft below grade .......... 0.096
6th ft below grade .......... 0.079

Total per ft length of wall .......... 0.621 Btu/(hr) (°F)
Basement perimeter ........ = 2(28 + 30) = 116 ft
Total wall heat loss .......... = 0.62 x 116 = 71.92 Btu/(hr) (°F)
say 72 Btu/(hr) (°F)

**Floor** (Using Table II):

Average heat loss per sq ft .......... = 0.025 Btu/(hr) (°F)
Floor area 28 x 30 .......... = 840 sq ft
Total floor heat loss .......... = 0.025 x 840 = 21 Btu/(hr) (°F)

**Total**

Total basement heat loss below grade = 72 + 21 = 93 Btu/(hr) (°F)
Design temperature difference ....... = 70 – 20 = 50°F
Hence, the maximum rate of heat loss from the below-grade basement = 93 x 50 = 4650 Btu/hr.

wall and the sill plate and of applying 2 in. of mineral wool insulation to the blocking between the floor joists and down the concrete wall for various depths is shown.

For calculation of the heat loss from the above-grade portion of the house the 2½ per cent design temperature for Ottawa is adopted, i.e., —13°F. For the below-grade portion the external design temperature ($T_a$ —A) for Ottawa is taken from Table III, i.e. +21°F. The internal temperature is taken as +72°F throughout. The values of heat loss obtained are summarized in Table IV, which indicates that the over-all calculated hourly heat loss from the house has been reduced by about one quarter.

**Sensation of Warmth of Unheated Basement Floors**

A problem often encountered in an occupied basement is that the floor feels cold. To raise the temperature of an unheated floor it is necessary to increase the thermal resistance of the heat flow path shown in Figure I. This path is, however, already a long one, and adding insulation (which may be considered the equivalent of lengthening it) will not have any marked effect. Furthermore, the use of insulation under the floor is rendered ineffective by two other factors. One, the high heat capacity of a floor will produce a sensation of cold until the body has remained stationary on that part of the floor long enough to warm it; and second, once the heat reaches a layer of high conductivity it can flow laterally, increasing the amount of material to be warmed.

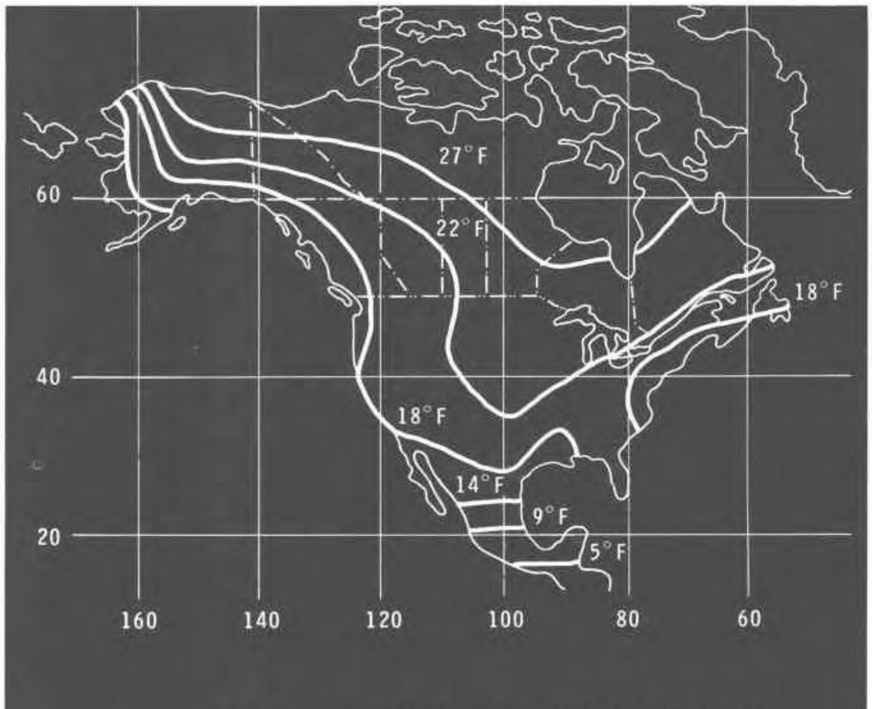


FIGURE 2 LINES OF CONSTANT AMPLITUDE

It is clear that in order to prevent a basement floor from feeling cold it is necessary to restrict the flow of heat from the body into the floor. This requires that an insulating material be placed between the body and the first layer of material that is of high conductivity. The most economical way for an adult to provide the necessary insulation is to wear thicker soled footwear. For children who may play on the floor this is not a practical solution and some form of carpeting should be provided. If there should be a problem of moisture rising through the floor, then the type of carpeting must be chosen with care.

**Position of Insulation**

In calculating heat loss the effect of insulation is allowed for by converting it to an equivalent thickness of soil. As far as total heat loss is concerned it makes no difference where

**TABLE IV**
**HEAT LOSSES FROM A TYPICAL BUNGALOW**

| | | Basement | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Totally Uninsulated | | Insul. to Grade and Sill Caulked | | Insul. to 1 ft below Grade and Sill Caulked | | Insul. to 2 ft below Grade and Sill Caulked | |
| | House Above First Floor | Above Grade | Below Grade | Above Grade | Below Grade | Above Grade | Below Grade | Above Grade | Below Grade |
| Transmission | 21330 | | | | | | | | |
| Infiltration | 7170 | | | | | | | | |
| Infiltration at sill | | 5600 | | 0 | 0 | 0 | 0 | 0 | 0 |
| Transmission | | | | | | | | | |
| (a) header | | 2020 | | 1060 | | 1060 | | 1060 | |
| (b) concrete wall | | 990 | 6470 | 3960 | 6470 | 3960 | 4940 | 3960 | 3020 |
| (c) floor | | | 1500 | | 1500 | | 1500 | | 1500 |
| Basement windows | | | | | | | | | |
| (a) transmission | | 1440 | | 1440 | | 1440 | | 1440 | |
| (b) infiltration | | 3180 | | 3180 | | 3180 | | 3180 | |
| | A | B | C | $D_0$ | $E_0$ | $D_1$ | $E_1$ | $D_2$ | $E_2$ |
| Sub-totals | 28500 | 22140 | 7970 | 9640 | 7970 | 9640 | 6440 | 9640 | 4520 |

| Total heat loss | | | |
|---|---|---|---|
| Basement uninsulated (A+B+C) | 58610 Btu/hr | 58610 Btu/hr | 58610 Btu/hr |
| Sill caulked and insulation to grade ($A+D_0+E_0$) | 46110 Btu/hr | | |
| Sill caulked and insulation to 1 ft below grade ($A+D_1+E_1$) | | 44580 Btu/hr | |
| Sill caulked and insulation to 2 ft below grade ($A+D_2+E_2$) | | | 43560 Btu/hr |
| Saving | 12500 Btu/hr (21.2 per cent) | 14030 Btu/hr (23.9 per cent) | 15050 Btu/hr (25.6 per cent) |

along the heat flow path this added length is inserted, and insulation laid on the surface of the ground is just as effective as the same amount placed on the inside surface of the wall. The temperature conditions in the wall and the soil will, however, be affected because everything outside the insulation will become colder.

Applying insulation to the inside face of the wall makes both the wall and the soil colder. The cold wall makes an air barrier in the room finish highly desirable to prevent any possibility of condensation on the wall behind the finish from convective air movement from the room into any cold spaces. The lower temperatures in the soil may also pose problems of frost heave, if the soil is frost susceptible, and of plant growth with some types of plants. Moving the insulation to the outside of the basement wall solves the problem of condensation in the room by keeping the wall warm, but it makes no difference to the soil temperature. The insulation, if of foamed plastic, needs no protection below grade, but near and above the surface it must be covered to protect it from damage and for aesthetic reasons. Should there be any frost heave this covering may be damaged. Laying the insulation horizontally just below the ground surface keeps the soil warm and thus solves the frost heave problem, but it requires that only shallow rooted plants be planted in the thin layer of soil above it.

## Conclusion

Heat losses from a house basement above grade can be calculated by the normal methods for walls and below grade by similar steady-state methods assuming circular heat flow paths through the soil. Insulation on the basement wall above grade is just as important as for any other wall above grade and care should be taken to prevent air leakage through the crack between the top of the concrete wall and the sill plate. The insulation should be carried down at least 1 to 2 ft below the grade line, but thereafter it becomes of progressively less value and may be difficult to justify economically. Insulation below the floor has no value and carpeting or other low conductivity floor finish should be used to counteract the sensation of a cold floor.

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1. Boileau, G. G. and Latta, J. K. Calculation of Basement Heat Losses. National Research Council of Canada, Division of Building Research, NRC 10477, Dec. 1968.
2. Chang, Jen-Hu. Ground Temperature. Vol. I and II. Bluehill Meteorological Observatory, Harvard University, 1958.


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