Plasterboard	0.32
Inside air	0.68
	$\Sigma R = 6.84$

$U = 1/R = 1/6.84 = 0.146$ Btu/h·ft²·°F

$A = 10 \times 50 = 500$ ft²

$\Delta t = 72 - 32 = 40$°F

$q_t = UA\Delta t = 0.146 \times 500 \times 40$

$= 2920$ Btu/h (0.856 kW)

6.4.2 Selecting Heating Design Conditions

The ideal solution to a basic heating system design is a plant with a maximum output capacity equal to the heating load that develops with the most severe local weather conditions. However, this solution is usually uneconomical. Weather records show that severe weather conditions do not repeat annually. If heating systems were designed for maximum weather conditions, excess capacity would exist during most of the system's operating life.

In many cases, an occasional failure of a heating plant to maintain a preselected indoor design temperature during brief periods of severe weather is not critical. However, the successful completion of some industrial or commercial processes may depend on close regulation of indoor temperatures. The specific requirements for each building should be carefully evaluated.

Before selecting an outdoor design temperature from chapter 4, the designer should consider the following:

- Is the type of structure heavy, medium, or light?
- Is the structure insulated?
- Is the structure exposed to high wind?
- Is the load from infiltration or ventilation high?
- Is there more glass area than normal?
- During what part of the day will the structure be used?
- What is the nature of occupancy?
- Will there be long periods of operation at reduced indoor temperature?
- What is the amplitude between local maximum and minimum daily temperatures?
- Are there local conditions that cause significant variation from temperatures reported by the Weather Bureau?
- What auxiliary heating devices will be in the building?

Before selecting an outdoor design temperature, the designer must keep in mind that, if the outdoor to indoor design temperature difference is exceeded, the indoor temperature may fall, depending on the thermal mass of the structure and its contents, whether or not the internal load was included in calculations, and the duration of the cold period.

The effect of wind on the heating requirements of any building should be considered because:

- Wind movement increases the heat transmission of walls, glass, and roof, affecting poorly insulated walls to a much greater extent than well-insulated walls.
- Wind increases the infiltration of cold air through cracks around doors and windows and even through building materials themselves.

Although 72°F to 75°F are the most commonly selected indoor temperatures for comfort heating design, local code requirements must be checked. ASHRAE Standard 55 and chapter 8 of the *2005 Fundamentals* provide additional details on selecting indoor design conditions.

6.4.3 Heat Loss from Above-Grade Exterior Surfaces

All above-grade surfaces exposed to outdoor conditions (walls, doors, ceilings, fenestration, and raised floors) are treated identically, as follows:

$$q = A \times HF$$

$$HF = U\,\Delta t$$

where *HF* is the heating load factor in Btu/h·ft².

Two ceiling configurations are common:

- For ceiling/roof combinations (e.g., flat roof or cathedral ceiling), the U-factor should be evaluated for the entire assembly.
- For well-insulated ceilings (or walls) adjacent to vented attic space, the U-factor should be that of the insulated assembly only (the roof is omitted) and the attic temperature assumed to equal the heating design outdoor temperature.

6.4.4 Heat Loss Through Below-Grade Surfaces

Heat transfer through basement walls and floors to the ground depends on (1) the difference between the air temperature within the room and that of the ground and outside air, (2) the material of the walls or floor, and (3) conductivity of the surrounding earth. Conductivity of the earth is usually unknown. Because of thermal inertia, ground temperature varies with depth, and there is a substantial time lag between changes in outdoor air temperatures and corresponding changes in ground temperature. As a result, ground-coupled heat transfer is less amenable to steady-state representation than is the case for above-grade building elements.

An approximate method for estimating below-grade heat loss finds the steady-state heat loss to the ground surface, as follows:

$$HF = U_{avg}\,(t_{in} - t_{gr})$$

where

U_{avg} = average U-factor for below-grade surface, Btu/h·ft²·°F

t_{in} = below-grade space air temperature, °F

t_{gr} = design ground surface temperature, °F

The effect of soil heat capacity means that none of the usual external design air temperatures are suitable values for t_{gr}. Ground surface temperature fluctuates about an annual mean value by amplitude A, which varies with geographic location and surface cover. The minimum ground surface temperature, suitable for heat loss estimates, is therefore

$$t_{gr} = t_m - A$$

where

t_m = mean winter temperature, estimated from the winter average air temperature or from well-water temperature

A = ground surface temperature amplitude from Figure 6-1

The value of the soil thermal conductivity k varies widely with soil type and moisture content. A typical value of 0.8 Btu/h·ft·°F was used to tabulate U-factors with an R-value of approximately 1.47 h·ft²·°F/Btu for uninsulated concrete walls. For these parameters, representative values for $U_{avg,bw}$ are shown in Table 6-18. Representative values of $U_{avg,bf}$ for uninsulated basement floors are shown in Table 6-19.

6.4.5 Heat Loss From On-Grade Surfaces

Concrete slab floors may be (1) unheated, relying for warmth on heat delivered above floor level by the heating system, or (2) heated, containing heated pipes or ducts that constitute a radiant slab or a portion of it for complete or partial heating of the house. Heat loss from a concrete slab floor is mostly through the perimeter rather than through the floor and into the ground. Total heat loss is more nearly proportional to the length of the perimeter than to the area of the floor. The simplified approach that treats heat loss as proportional to slab perimeter allows slab heat loss to be estimated for both unheated and heated slab floors:

$$q = P \times HF$$

$$HF = F_p \, \Delta t, \text{ or}$$

$$q = F_p P \, (t_i - t_o) \qquad (6\text{-}25)$$

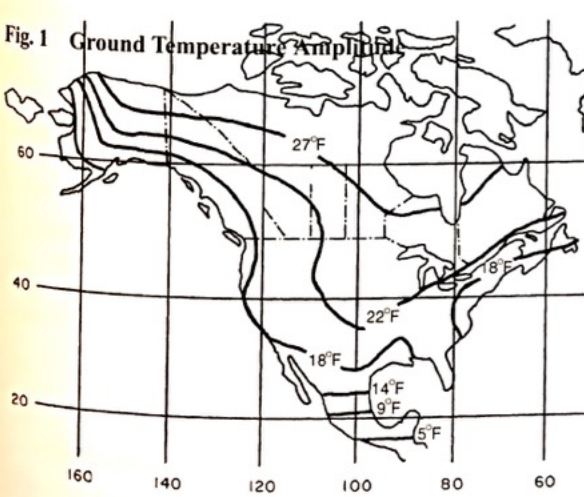

Fig. 6-1 Ground Temperature Amplitude

where

q = heat loss through the perimeter, Btu/h (W)

F_p = heat loss coefficient, Btu/h·°F·ft of perimeter [W/(m · K)]

P = perimeter of exposed edge of floor, ft (m)

t_i = indoor temperature, °F (°C)

t_o = outdoor design temperature, °F (°C)

Representative heat loss coefficients for slab-on-grade floors are available from Table 6-20.

Example 6-2 Determine the heat loss for a basement in St. Louis, Missouri, which is 60 ft by 40 ft by 8 ft high, of standard concrete construction and entirely below grade. Average winter temperature in St. Louis is 44°F.

Design $\Delta t = t_i - (t_a - A) = 70 - (44 - 22) = 48$ (Figure 6-1)

Wall Average U-Factors (Table 6-18): 0.157 Btu/h·ft°F

$$HF = U \times \Delta t = 0.157\,(48) = 7.54$$

Wall loss = HF × A = 7.54 (200 × 8) = 12060 Btu/h

Floor Heat Loss (Table 6-20)

$$U_{floor} = 0.026 \text{ Btu/h} \cdot \text{ft}^2 \cdot °\text{F}$$

$$\text{Area} = 60 \times 40 = 2400 \text{ ft}^2$$

$$\text{Floor heat loss} = 0.026\,(2400)\,48 = 3000 \text{ Btu/h}$$

$$q_{total} = 12060 + 3000 = 15{,}060 \text{ Btu/h (4.41 kW)}$$

6.4.6 Heat Loss To Buffer Spaces

Heat loss to adjacent unconditioned or semiconditioned spaces can be calculated using a heating load factor based on the partition temperature difference:

Table 6-18 Average U-Factor for Basement Walls with Uniform Insulation

	$U_{avg,bw}$ from grade to depth, Btu/h·ft²·°F			
Depth, ft	**Uninsulated**	**R-5**	**R-10**	**R-15**
1	0.4321	0.1351	0.080	0.057
2	0.331	0.121	0.075	0.054
3	0.273	0.110	0.070	0.052
4	0.235	0.101	0.066	0.050
5	0.208	0.094	0.063	0.048
6	0.187	0.088	0.060	0.046
7	0.170	0.083	0.057	0.044
8	0.157	0.078	0.055	0.043

Soil conductivity = 0.8 Btu/h·ft·°F; insulation is over entire depth.

Table 6-19 Average U-Factor for Basement Floors

	$U_{avg,bf}$, Btu/h·ft²·F			
z_f (depth of floor below grade), ft	**w_b (shortest width of basement), ft**			
	20	**24**	**28**	**32**
1	0.064	0.057	0.052	0.047
2	0.054	0.048	0.044	0.040
3	0.047	0.042	0.039	0.036
4	0.042	0.038	0.035	0.033
5	0.038	0.035	0.032	0.030
6	0.035	0.032	0.030	0.028
7	0.032	0.030	0.028	0.026

Soil conductivity is 0.8 Btu/h·ft·°F; floor is uninsulated.