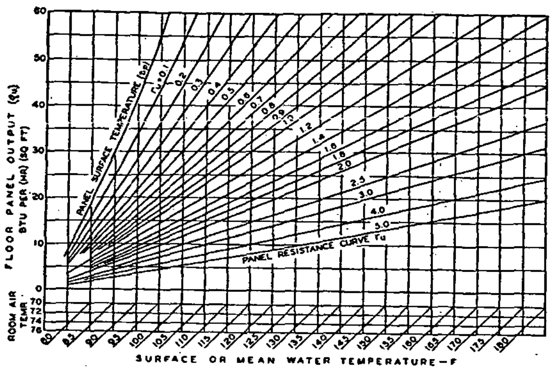

Fig. 16 . . . . Floor Panel Design Graph Showing Panel Surface Temperature and Mean Water Temperature vs Output Upward

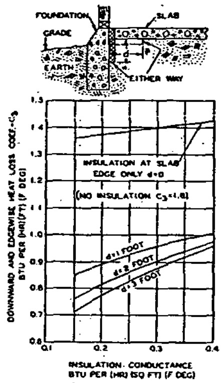

Fig. 17 . . . . Downward and Edgewise Heat Loss Coefficient for Concrete Floor Slabs on Grade

slab. To maintain a given upward heat flow after a floor covering has been added, the temperature of the heating medium must be increased. Data on the thermal resistance of common floor coverings are given in Table 4, and the application of the data is illustrated in *Example 2*.

Where covered and bare floor panels exist on the same system, it may be possible to maintain the water temperature high enough to satisfy the covered panels, and balance the system by throttling the flow to the bare slabs. In some instances, however, the large increase in water temperature required when carpeting is applied over floor panels will make it impossible to balance floor panel systems in which carpeting is used in some rooms only, unless the pipe is arranged to permit zoning with the use of more than one water temperature.

Panel Heat Losses

Heat transferred from the upper surface of ceiling panels, the back surface of wall panels, the underside of floor panels, or the edges of any panel is considered a panel heat loss. Panel heat losses are part of the building heat loss if the heat is transferred outside of the building. If the heat is transferred to another heated space, the panel loss is a source of heat for the space and is not a part of the building heat loss. In either case, the magnitude of the panel loss should be determined.

Panel heat loss to the space outside the room should be kept to a reasonable amount by insulation. Panel heat loss to heated spaces may require reduction by insulation if the amount of heat transferred is excessive or if objectionable temperatures will be developed. For example, a floor panel may overheat the basement below and a ceiling panel may cause the temperature of a floor surface above it to be too high for comfort.

The heat loss from most panels can be calculated by using the coefficients given in Chapter 23, Design Heat Transmission Coefficients, of the 1961 Guide And Data Book. These coefficients should not be used to determine the downward heat loss from panels built on grade because the heat flow from them is not uniform.[10,11,12] The heat loss from panels built on grade can be estimated from Fig. 17.

DESIGN OF PANEL HEATING SYSTEMS

Design Steps

Panel design requires specification of the following: panel area, size and location of the heating elements in the panel, insulation on the reverse side and edge of the panel, required input to panel, and temperature of the heating elements. The procedure is summarized as follows:

1. Calculate the hourly rate of heat loss for each room.
2. Determine the available area for panels in each room.
3. Calculate the required unit panel output.
4. Determine the required panel surface temperature.
5. Select the means of heating the panel and the size and location of the heating elements.
6. Select the insulation for the reverse side and edge of the panel.
7. Determine the panel heat loss and the required input to the panel.
8. Determine the other temperatures which are required or developed.
9. Design the system for heating the panels in accordance with conventional practice.

In the steps outlined for design, the effect of each assumption or choice on comfort should be considered carefully. The following general rules may be followed:

1. Place panels near the cold areas where the heat losses occur.
2. Do not use high temperature ceiling panels in very low ceilings.
3. Keep floor temperatures at or below recommended limits.

Warm Water Panels

This section contains a simplified procedure for the thermal design of water-heated panels for use in residences and commercial buildings. The procedures are based primarily on the experimental data obtained at the ASHRAE Research Laboratory. This work has been reported in a series of research papers which are listed in the references and bibliography at the end of this chapter.

A panel designed by these procedures will maintain the desired room air temperature for the selected outdoor conditions. Room air temperature is the selected criterion of comfort. The design procedure is restricted to situations in which the area-weighted average temperature of unheated surfaces of walls, glass, and floor or ceiling does not differ greatly from room air temperature. Room-scale tests, which simulated various conditions of construction and outdoor temperature, have shown that this near-equality of the two temperatures normally prevails.

The procedures are applicable within the following range:

Outdoor design conditions: Temperatures as low as −30 F.

Room air temperature: 70 to 76 F.

Air changes: No more than two air changes per hour.

Room dimensions: Rooms having normal proportions; ceiling height between 7 and 12 ft.

Room construction: Any type of wall construction and any amount of glass area. (Both, however, have an effect upon comfort.) Conventional interior finishes and furnishings.

Design Examples

In the design examples which follow use is made of the letter symbols shown in the table Letter Symbols for Examples of Design Methods.

Letter Symbols for Examples of Design Methods

A_p = panel area, square feet.
C_1 = coefficient of heat transfer from the *upper* surface of the concrete slab which forms the ceiling panel to air above panel at point t_b, Btu per (hour) (square foot) (Fahrenheit degree temperature difference between panel surface and air).
C_2 = coefficient of heat transfer from *lower* surface of concrete slab to air below the panel at point t_b, Btu per (hour) (square foot) (Fahrenheit degree temperature difference between panel surface and air).
C_3 = coefficient of downward and edgewise heat loss of exposed slab, Btu per (hour) (linear foot of exposed slab perimeter) (Fahrenheit degree difference between concrete surface and outdoor air).
P = length of exposed edge of slab, feet.
q_d = downward heat flow from panel, Btu per (hour) (square foot).
q_{de} = apportioned downward and edgewise heat flow from panel, Btu per (hour) (square foot).
q_u = upward heat flow from panel, Btu per (hour) (square foot).
r_d = total thermal resistance of panel to downward heat flow, (Fahrenheit degree) (hour) (square foot) per Btu.
r_{dc} = thermal resistance of material between the underside of the concrete slab and the ceiling surface below, (Fahrenheit degree) (hour) (square foot) per Btu.
r_{ds} = thermal resistance of bare concrete panel to downward heat flow, (Fahrenheit) (hour) (square foot) per Btu.
r_u = total thermal resistance of panel to upward heat flow (Fahrenheit degree) (hour) (square foot) per Btu.
r_{uc} = thermal resistance of floor covering, (Fahrenheit degree) (hour) (square foot) per Btu.
r_{us} = thermal resistance of bare concrete slab to upward heat flow, (Fahrenheit degree) (hour) (square foot) per Btu.
t_a = design room air temperature, Fahrenheit.
t_{oa} = outdoor design air temperature, Fahrenheit.
t_b = air temperature above or below panel at point to which U, C_1, or C_2 is taken, Fahrenheit.
t_i = inlet water temperature, Fahrenheit.
t_o = outlet water temperature, Fahrenheit.
t_{mw} = mean water temperature, Fahrenheit.
t_{max} = maximum water temperature permissible for a given construction, Fahrenheit.
t_{dmw} = design mean water temperature (selected for each zone), Fahrenheit.
t_p = panel surface temperature, (exposed surface) Fahrenheit.
t_s = surface temperature of top of concrete slab, Fahrenheit.
U = overall coefficient of heat transfer for the given construction between room air and the point t_b, Btu per (hour) (square foot) (Fahrenheit degree temperature difference).

Procedure for Plaster Ceiling Panels[13]

The procedure for designing a plaster ceiling panel will be illustrated by *Example 1*.

Example 1: Three rooms, A, B, and C, are to have a common water supply temperature; that is, they represent a single zone. They are to be maintained at 72 F air temperature when the outdoor air temperature is zero F. The ceilings of rooms A and B have floors above them with the space heated to 72 F and an air-to-air U value of 0.25 Btu per (hr) (sq ft) (F deg). The ceiling of room C has insulation in the joist spaces and an uninsulated attic space with a combined U value of 0.05 from room C to outdoor air.

Step 1. Heat Loss

Calculate the heat loss of each room by methods outlined in Chapter 25 of the 1961 Guide And Data Book, but do not include any heat loss through the area covered by the panel.

Room dimensions and calculated heat losses are as follows:

Room	Dimensions Feet	Heat Loss Btu per hour
Room A	11 x 12 x 8	6300
Room B	11 x 12 x 8	2500
Room C	15 x 21 x 8	8000

Step 2. Required Panel Output

Divide the heat loss of each room by the maximum ceiling area in the room which can be used as a heating panel. The result is the minimum heat output per square foot of panel that will satisfy the requirements of the room. The panel that requires the highest output per square foot will generally control the design, because the temperature of the fluid in the system must be high enough to produce the required out-