In the following example, *it will be assumed that the ceiling panel must deliver 70 per cent of its heat or 24,582 Btuh by radiation,* since the total calculated heat loss is 35,117.

When two plane surfaces of infinite size are parallel to each other and their surfaces are at different temperatures, the exchange of heat between the two is proportional to the difference between the fourth powers of their absolute temperatures. This is also true when one surface is completely surrounded by another surface; for example, if one sphere is placed within another sphere, the flow of heat between the outer surface of the smaller sphere and the inner surface of the larger sphere is proportional to the fourth power of the absolute temperatures of the two surfaces.

In a panel-heated room, the heated panel may be considered to be completely enclosed by the remaining surfaces, because all heat radiated by the heated panel is intercepted by those surfaces. Consequently, the flow of heat from the heated ceiling to the room, by radiation, is proportional to the difference between the fourth powers of the absolute temperature of the ceiling and the absolute mean radiant temperature of the remaining surfaces.

The rate at which a surface emits heat varies with the temperature of the surface and with other characteristics of the surface. For ordinary heat flow calculations, it

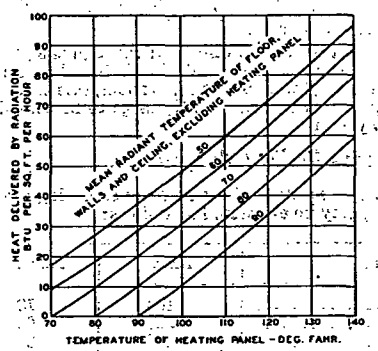


FIG. 9. HEAT DELIVERED TO ROOM BY RADIATION FROM PANEL

is sufficiently accurate to assume that the materials which are commonly used in building construction emit heat at a rate of:

$$0.156 \left(\frac{T}{100}\right)^4 \text{ Btuh per square foot}$$

where T is the absolute temperature of the surface in Fahrenheit degrees.

On this basis the flow of heat from the ceiling to its surrounding surfaces is at the rate of:

$$480 \times 0.156 \left[\left(\frac{T}{100}\right)^4 - \left(\frac{522}{100}\right)^4\right] \text{ Btuh.}$$

In order that this rate may be equal to 24,582 Btuh, T must be 572 and the ceiling temperature about 112 F.

Instead of calculating this temperature, it may be taken from Fig. 9, as follows: The ceiling must deliver heat to the room, by radiation, at the rate of 24,582/480 or 51 Btuh per square foot. Find 51 on the left margin and move horizontally to the intersection with a 62 MRT line, and from the point of intersection to the lower margin and read about 112 F.

With a ceiling temperature of 112 F, the MRT of the room will be 480 × 112 + 1,536 × 62; the sum divided by 2,016, or 74 F.

If an air temperature of 68 F and an MRT of 74 F should not produce satisfactory

conditions, the ceiling temperature can easily be changed as necessary by changing the temperature of the circulating water.

7. Select the medium for heating the ceiling panel.

The medium may be electricity, steam, air, or water, but usually is air or water. If air is used, it is generally heated in the basement, passed up through hollow inside walls or through ducts in those walls, allowed to flow between the ceiling and the floor above, and returned to the basement through hollow outside walls or through ducts in those walls.

If the walls and floors are constructed of hollow tile, the cells in the tile can be placed so that they will form continuous ducts through which the warm air can flow up the inside walls, then between the ceiling and the floor above, and down the outside walls. In this way the walls and ceiling become heating panels.

If water is used as the medium, the pipes through which the water circulates (almost always under forced circulation)are placed in the floor, walls, or ceiling in such a manner that the largest possible proportion of the heat emitted by the pipes will be delivered to the space to be heated.

Practical limits for surface temperatures of heating panels are given in Table 2.

TABLE 2. HIGHEST SAFE SURFACE TEMPERATURES FOR HEATING PANEL

TYPE OF PANEL	SURFACE TEMPERATURE F DEG
Plastered Ceiling (Pipes Imbedded)[a]	115
Plastered Walls (Pipes Imbedded)[a]	120
Floor, Any Method	85
Floor, Border and Aisles	120
Iron, Hot Water Medium[b]	160
Iron, Steam Vapor[a]	180
Electrically Heated Panels[b]	200

[a] *Gypsum Association* recommends that panels in which gypsum plaster or gypsum products are used should not have a surface temperature exceeding 115 F.
[b] Low surface temperature radiation is recommended regardless of the heating medium employed.

8. In this example water will be selected as the medium. Determine the size, length, and location of the pipe coils in the panels.

When hot-water pipes are imbedded in concrete slabs or attached to plastered surfaces, their rate of heat emission varies with many factors. If the pipes are imbedded in dense concrete slabs, it may be assumed that the rate of heat emission of ½-in. pipe, spaced 6 in. on centers; ¾-in. pipe, spaced 9 in. on centers; and 1-in. pipe spaced 12 in. on centers; per foot of length of pipe and per degree difference between the temperature of the water in the pipe and that of the air in the space to be heated, is 0.8, 1.0, and 1.2 Btuh, respectively. If the distance between the pipes is increased, the rate of heat emission, per foot of pipe, is also increased; if the distance is doubled, the rate of heat emission is increased about 15 per cent. If the pipes are attached to plastered ceilings, the rate of heat emission is slightly less, probably about 10 per cent less, than when the pipes are imbedded in concrete slabs. The data given regarding heat emission of panels are intended as general guides for the designer. Additional experience and research are needed to develop definite and complete data. However, after a heating panel has been designed and installed, any small error can easily be corrected by modifying the temperature of the water circulating through the coils.

When the heating pipes are attached to a plastered ceiling, a portion of the heat emitted by the pipes is delivered to the space below the ceiling, and a portion to the space above the ceiling. The relative quantities depend on the degree of insulation applied above the heating coils.

When the heating pipes are imbedded in a concrete floor slab, a portion of the heat emitted by the pipes will flow upward into the space to be heated, and the remainder will flow downward into the ground.

When the heating pipes are placed below the concrete floor slab instead of being