surface using a lower temperature circulating water. Also with the entire ceiling heated a slight margin of safety will be provided which is an advantage.

Example 2. Using the data in Example 1 calculated directly the required surface temperature if the entire ceiling area is utilized and the design room conditions are identical.

Solution. From Example 1 it was shown that 256,000 Btu per hour were required to maintain the desired MRT in the room having a surface area of 2016 sq ft, and that 24,500 Btu of additional heat per square foot of ceiling was required above the natural heat emission of the room as shown in Table 3. Dividing 24,500 by 480 = 51.0 Btu per square foot per hour plus 119.8 Btu per square foot per hour which is the heat emission of the unheated ceiling gives 170.8 Btu. From Table 1 and for an emissivity of 0.95

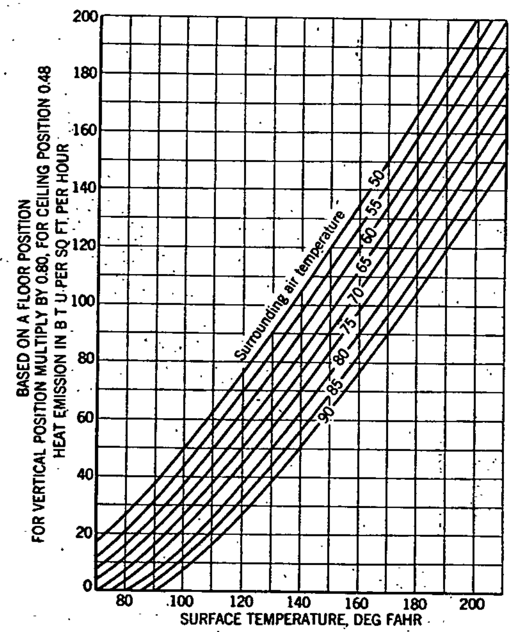

FIG. 9. HEAT EMISSION BY CONVECTION FROM RADIANT HEAT PANELS WITH STILL AIR AT VARIOUS TEMPERATURES

it is found that this amount of heat will be emitted from a surface at approximately 108.5 F.

This surface temperature may be obtained by using circulating water at about 125 F instead of 130 F, or the embedded pipes may be spaced wide apart and the water temperature maintained at 130 F.

Example 3. Determine the total heat emitted from the ceiling surface in Example 1 if it is maintained at a temperature to provide a room MRT of 71 F using the data in Figs. 8 and 9.

Solution. The calculated heat losses of the room as outlined in Chapter 6 are given in Table 4. The MRT for all unheated surfaces in the room may be determined from Table 3, by adding the total heat emission from walls, floors and windows and dividing by the total surface, or 174,000 ÷ 1536 = 113.5 Btu per square foot per hour. From Table 1 this emission from a surface having an emissivity of 0.93 corresponds to about 55 F.

Utilizing the entire ceiling area with a heat emission corresponding to a surface temperature of 108.5 F as determined in Example 2, and with a surrounding average MRT of the unheated surfaces of 55 F as previously calculated, it will be found from Fig. 8 that the ceiling surface will emit 50 Btu per square foot per hour by radiation. With an air temperature of 65 F this same surface will emit (42 × 0.48) = 20.2 Btu per square foot per hour by convection according to Fig. 9. Then the,

Total by radiation	= 480 × 50	=	24,000
Total by convection	= 480 × 20.2	=	9,696
			33,696 Btu per hour

The difference between 33,696 and 33,460 Btu in Table 4 results in a safety factor of 236 Btu per hour.

In case the ventilation rate of the room had been increased, more heat could be furnished by either adding wall panels or by introducing a positive source of ventilation air which could be externally heated to the correct temperature.

TABLE 4. CALCULATED HEAT LOSSES FOR EXAMPLE

SURFACE	AREA SQ FT	U	HEAT LOSS CALCULATION	TOTAL HEAT LOSS BTU PER HOUR
Outside Wall	297	0.25	297 × 0.25 × (65 − 0)	4,820
Exposed Glass	186	1.13[a]	186 × 1.13 × (65 − 0)	13,650
Covered Glass	93	0.57[b]	93 × 0.57 × (65 − 0)	3,440
Inside Wall	480	......	No heat loss next to heated room	....
Ceiling	480	......	Heated surface	....
Floor	480	0.10	480 × 0.10 × (65 − 0)	3,120
Infiltration	5760 cu ft × 1.25 air changes × (65 − 0) × 0.018			8,430
			Total	33,460

[a]Two-thirds window area assumed to be fully exposed with a $U = 1.13$.
[b]One-third window area protected by side curtains with a reduction $U = 0.57$.

MEASUREMENT OF RADIANT HEATING

Convection heating, intended to maintain a given air temperature, is best measured by thermometric methods, which indicate the air temperature, and not the rate of heat loss from the human body. Radiant heating aims to control this rate of heat loss and can be measured only by calorimetric methods.

The apparatus for this purpose consists essentially of a cylinder, maintained at the accepted mean surface temperature of the human body, together with an accurate (usually electrical) measuring of the varying rate of heat supply required to maintain this exact temperature. This instrument, the *eupatheoscope*, is readily adapted to function like a thermostat so as to turn heat on or off, when the desired temperature of 80 F, or any other predetermined surface temperature of the cylinder, decreases or increases as a result of changes in the BET.

For testing work, the *globe thermometer* is a useful instrument. It consists of an ordinary mercury thermometer, with its bulb placed in the center of a sphere from 6 to 9 in. in diameter, usually made of thin copper and painted black and sometimes covered with cloth. The temperature