

reduced from a given temperature to a lower temperature, the amount of heat lost from the body by convection is increased, and this increase can be compensated for by raising the MRT. Similarly, with a higher air temperature the same total heat loss will be maintained by a correspondingly lower MRT.

The loss by evaporation depends on the air temperature, air movement, and humidity; it is increased if the humidity is reduced. For the usual conditions of heating by radiators or convectors, where the air temperature ranges from 70 F to 73 F, approximately 75 per cent of the total heat loss of 400 Btu per hour occurs by radiation and convection, and the balance, or 100 Btu per hour, occurs by evaporation. In the case of radiant heating, if the air temperature is reduced to 60 F, 84 per cent of the 400 Btu per hour, or 336 Btu per hour, is lost by radiation and convection, and 64 Btu per hour are lost by evaporation.

The mean normal surface temperature of the human body, taken over the whole area, including not only the exposed skin surface but also surfaces of the clothes and the hair, has been very extensively used as 75 F, particularly in British literature. However, results obtained by Aldrich² in rooms in which the air and wall surface temperatures were approximately 72 F gave mean values nearer to 83 F than 75 F.

The mean body surface temperature which will maintain the optimum heat loss by radiation and convection in a uniform environment of 72 F may be calculated from fundamental equations for radiation and natural convection by substituting a comparable cylinder for the body. Heilman³ gives the following equations:

$$H_r = 0.1723 \epsilon \left[\left(\frac{T_s}{100} \right)^4 - \left(\frac{T_w}{100} \right)^4 \right] \quad (1)$$

$$H_c = 1.235 \left(\frac{1}{D} \right)^{0.2} \times \left(\frac{1}{T_m} \right)^{0.181} \times (T_s - T_a)^{1.266} \quad (2)$$

where

H_r = heat loss by radiation in Btu per square foot per hour.

H_c = heat loss by convection in Btu per square foot per hour.

T_s = absolute temperature of the body surface in degrees Fahrenheit.

T_w = absolute temperature of the walls in degrees Fahrenheit.

T_a = absolute temperature of the air in degrees Fahrenheit.

$$T_m = \frac{T_s + T_a}{2}$$

D = diameter of cylinder in inches.

ϵ = the ratio of actual emission to black body emission.

By assuming for a normal adult an average height of 5 ft 8 in. and an average body surface of 19.5 sq ft, an equivalent diameter of 13.15 in. is obtained. The value of ϵ for skin and clothing is practically 0.95. If both T_a and T_w are taken as 72 F, or 532 absolute, and the sum of H_r and H_c is made 15.4 Btu per square foot per hour, solution of these equations gives a value of approximately 83 F for the normal temperature

²A study of Body Radiation, by L. B. Aldrich (Smithsonian Miscellaneous Collections, Vol. 81, No. 6, December, 1928).

³Surface Heat Transmission, by R. H. Heilman (Trans. A.S.M.E., Fuels and Steam Power Section, Vol. 51, No. 22, September-December, 1929).

of the body surface. This agrees more closely with the values obtained by Aldrich than with the 75 F used by British investigators.

British Equivalent Temperature

The British equivalent temperature (BET) is an index number used in radiant heating considerations which indicates the rate of heat loss, by radiation and convection only, from a body in still air maintained at a surface temperature of 83 F. As originally defined, this index was based on a surface temperature of 75 F, but 83 F has been accepted as giving results more nearly conforming with American practice⁴. When the mean radiant temperature is the same as the air temperature, this value is also that of the BET, but when there is a difference between the two, the BET is always intermediate. The higher the BET, the less the heat loss from the body, the rate of loss in still air being approximately proportional to the difference between the BET and the mean body surface temperature.

If the BET were 83 F, there could be no loss of heat from a surface at that temperature, so the temperature of a normal body surface would have to rise to a point where the heat generated in the tissues could be dissipated.

When convected heat is used, the temperatures of the air and walls are nearly the same, and the optimum value of the BET from the physiological point of view is 72 deg Fahr. Under these conditions the mean surface temperature of a normal body would have the optimum value of 83 F because the rate of heat loss by radiation and convection would be 15.4 Btu per square foot per hour and that by evaporation, 5.1 Btu per square foot per hour, which would just balance the rate of heat production of 20.5 Btu per square foot per hour. This BET of 72 deg Fahr in a uniform environment is exactly equivalent to the *effective temperature* of 66 deg Fahr as defined by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS (see Chapter 2), because, in a uniform environment, a dry bulb temperature of 72 F in still air with a relative humidity of 30 per cent gives an *effective temperature* of 66 deg Fahr, which has been determined to be the optimum.

In radiant heating, where the air may differ considerably in temperature from the surrounding objects, a change occurs in the relations among the heat lost by radiation, convection, and evaporation. It would seem, therefore, that a modification should be made in the optimum BET. If the air temperature drops as low as 60 F the heat loss by evaporation is reduced to 64 Btu per hour, and that by radiation and convection must be increased to 336 Btu per hour in order to maintain the total loss of 400 Btu per hour needed for optimum comfort. This 336 Btu per hour, or 17.2 Btu per square foot per hour, corresponds to a BET of 71 deg Fahr. Hence, for all practical purposes, the optimum BET of 72 deg Fahr may be regarded as applicable to both convection heating and radiant heating.

METHODS OF APPLICATION

There are two general methods of application of radiant heating, as follow:

⁴Application of the Eupatheoscope for Measuring the Performance of Direct Radiators and Convectors in Terms of Equivalent Temperatures, by A. C. Willard, A. P. Kratz, and M. K. Fahnestock (A.S.H.V.E. Journal, Heating, Piping and Air Conditioning, July, 1933).