adaptations of the Vernon Globe thermometer, incorporating thermocouples rather than mercury thermometers, have been found more satisfactory and convenient.

Such instruments as these, when properly calibrated and their readings are compared, can be used for determining the four basic physical factors concerned separately or in certain combinations. The results of the four physical measurements thus determined can generally be translated into the terms of any special instrument combining two or more of them.

The work of the A.S.H.V.E. Research Laboratory has made available psychrometric charts with effective temperature scale superimposed thereon, including Figs. 8 and 9, and others[56], while recent studies[57] have indicated the degree to which mean radiant temperature of the surroundings modify the effective temperature index.

In some instances it may be important to record not only the movement and temperature of the air at various levels, but also the temperature of each wall and window, of the flooring, and of the ceiling, and to measure the total effective radiation of the surroundings in 6 directions; in order to trace the exact causes of defects in the building which have an unfavorable influence on the heat exchanges of its inhabitants. Facts of this type are of great practical importance.

[56]A.S.H.V.E. RESEARCH REPORT No. 691—Cooling Effects on Human Beings Produced by Various Air Velocities, by F. C. Houghten and C. P. Yaglou (A.S.H.V.E. TRANSACTIONS, Vol. 30, 1924, p. 193).
[57]Loc. Cit. Note 31

Chapter 3

FUNDAMENTALS OF HEAT TRANSFER

Conduction, Convection, Radiation, Combined Convection and Radiation, Heat-Flow Resistance, Electrical Analogies, Practical Heat Transfer Problems, Unit Conductances for Convection Flow Systems, Radiation Factors or Emissivities, Solutions for Steady-State Conduction Problems

HEAT is that form of energy which is transferred from place to place by virtue of an existing temperature difference. The temperature difference is the potential which causes the transfer, the latter in turn being resisted by the thermal properties of the material combined in a simple term and known as the resistance. Energy exchange associated with mass transfer from place to place (evaporation, condensation, etc.) due to concentration differences will be treated elsewhere such as the section on *cooling tower design* in Chapter 27. The objectives of this chapter are to:

1. Describe the mechanisms and present the rate equations for the different modes of heat transfer.
2. Illustrate the application of the basic concepts to steady-state problems (temperature independent of time or a cyclic variable thereof) by means of several typical solutions of heat transfer systems.

Further applications to specific systems will be found throughout the Guide.

CONDUCTION, CONVECTION AND RADIATION

Thermal conduction is the term applied to the mechanism of heat transfer whereby in fluids the molecules of higher random kinetic energies transmit by direct molecular collision part of their energy to adjacent molecules of lower random kinetic energy. Since the temperature is proportional to the random kinetic energy of the molecules, thermal transfer will occur in the direction of decreasing temperature. The molecules oscillate about a mean position at fairly high velocities and frequencies, but there is no net material flow associated with the conduction mechanism.

In solids the significant mechanism of heat transport is thermal conduction and is ascribed to a transfer mechanism associated with the free electrons[1]. Even in the case of fluids, thermal conduction is significant in the region very close to a solid boundary or wall, for in this region the flow is laminar, parallel with the wall surface, and there are practically no cross currents in the direction of the heat transfer.

[1]The Metallic State, by H. Hume-Rothery (Oxford Press, 1931).