steady-state heat transfer problems. There are many problems which cannot be approximated by steady-state solutions. For instance, the problem of pipe line insulation in transient service; the behavior of automatically controlled thermoflow circuits; or the periodic absorption of solar energy by roof and wall structures during the day and nocturnal radiation to the *cold* sky at night. The transient heat transfer problem differs from the steady-state in that energy storage rates need to be considered. Thus thermal capacity in addition to resistance effects are significant. The vector sum of the thermal capacitance and resistance is the thermal impedance. It is not within the scope of this chapter to deal with many of these problems. There are, however, solutions available in graphical form for certain special cases. Also a general approximate method may be employed which is analogous to the treatment of capacity-resistance lumped parameter electrical circuits.

REFERENCES

Heat Transmission, by W. H. McAdams (McGraw-Hill Book Co., 1942).

Introduction to Heat Transfer, by A. I. Brown and S. M. Marco (McGraw-Hill Book Co., 1942).

Elements of Heat Transfer and Insulation, by Max Jakob and G. A. Hawkins (John Wiley and Sons, Inc., 1942).

Applied Heat Transmission, by H. J. Stoever (McGraw-Hill Book Co., 1941).

Industrial Heat Transfer, by A. Schack, translated from the German by H. Goldschmidt and E. P. Partridge (John Wiley and Sons, Inc., 1933).

The Calculation of Heat Transmission, by Margaret Fishenden and O. A. Saunders (His Majesty's Stationery Office, London).

Heat and Thermodynamics, by M. W. Zemansky (McGraw-Hill Book Co., 1937).

CHAPTER 4

Heat Transmission Coefficients

Transfer Through Building Surfaces, Heat Transfer Symbols, Formulas for Calculating Over-all Coefficients, Conductivity of Homogeneous Materials, Surface Conductance Coefficients, Air Space Conductance, Practical Coefficients, Computed Transmission Coefficients, Combined Coefficients of Transmission, Basement Floor and Wall Coefficients, Condensation in Buildings

IN order to calculate the heat transfer through walls, ceilings, floors and other parts of a structure it is necessary to know the *rate* of heat transfer through these surfaces. This rate of heat transfer is designated as the coefficient of transmission and can be determined by test in the guarded hot box apparatus, or calculated if certain constants are known. Because of the many possible combinations of materials in building construction, it is impractical to test each individual construction. Instead the over-all coefficients of transmission are calculated from the individual or component conductivities and conductances according to the procedure described in this chapter.

TRANSFER THROUGH BUILDING SURFACES

A general discussion of the three methods of heat transfer—conduction, convection and radiation—will be found in Chapter 3. The heat transmission between the air on the two sides of a structure takes place by a combination of the three methods. In a simple wall built up of two layers of homogeneous materials separated to give an air space between them, heat will be received from the high temperature surface by radiation, convection and conduction. It will then be conducted through the homogeneous interior section by conduction and carried across to the opposite surface of the air space by radiation, conduction and convection. From here it will be carried by conduction through to the outer surface and leave the outer surface by radiation, convection and conduction.

HEAT TRANSFER SYMBOLS

The symbols representing the various coefficients of heat transmission and their definitions are:

U = over-all coefficient of heat transmission; the amount of heat expressed in Btu transmitted in one hour per square foot of the wall, floor, roof or ceiling for a difference in temperature of 1 F between the air on the inside and that on the outside of the wall, floor, roof or ceiling.

k = thermal conductivity; the amount of heat expressed in Btu transmitted in one hour through 1 sq ft of a homogeneous material 1 in. thick for a difference in temperature of 1 F between the two surfaces of the material. The conductivity of any material depends on the structure of the material and its density. Heavy or dense materials, the weight of which per cubic foot is high, usually transmit more heat than light or less dense materials, the weight of which per cubic foot is low.

C = thermal conductance; the amount of heat expressed in Btu transmitted in one hour through 1 sq ft of a material for the thickness or type under consideration for a difference in temperature of 1 F between the two surfaces of the material. Conductance is usually used to designate the heat transmitted through such heterogeneous materials as plasterboard and hollow clay tile.

f = film or surface conductance; the amount of heat expressed in Btu transmitted by radiation, conduction and convection from a surface to the air surrounding it, or vice versa, in one hour per square foot of the surface for a difference in temperature of 1 F between the surface and the surrounding air. To differentiate between inside and outside