$\frac{1}{C}$ = resistance of a material (surface-to-surface)

$\frac{1}{f}$ = film or surface resistance

$\frac{1}{a}$ = air space resistance

CALCULATING OVER-ALL COEFFICIENTS

From Chapter 5, Equation 7, the total resistance to heat flow through a wall is equal numerically to the sum of the resistances in series. Then by definition,

$$U = \frac{1}{R_t} = \frac{1}{R_1 + R_2 + R_3 + \cdots + R_n} \qquad (1)$$

where

R_1, R_2, etc. are the individual resistances of the wall components.

R_t = total resistance.

For a wall of a single homogeneous material of conductivity k and thickness x, with surface coefficients f_i and f_o

$$U = \frac{1}{R_t} = \frac{1}{\frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o}} \qquad (2)$$

For a compound wall of three homogeneous materials in series, having conductivities k_1, k_2 and k_3 and thicknesses x_1, x_2 and x_3 respectively, and laid together without air spaces,

$$U = \frac{1}{R_t} = \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{x_2}{k_2} + \frac{x_3}{k_3} + \frac{1}{f_o}} \qquad (3)$$

For a wall with air space construction and consisting of two homogeneous materials of conductivities k_1 and k_2, thicknesses x_1 and x_2, and separated by an air space of conductance a

$$U = \frac{1}{R_t} = \frac{1}{\frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{a} + \frac{x_2}{k_2} + \frac{1}{f_o}} \qquad (4)$$

In the case of types of building materials having non-uniform or irregular sections such as hollow clay tile or concrete blocks, it is necessary to use the conductance C of the section unit as manufactured instead of a conductivity k. The resistance of the section $\frac{1}{C}$ is therefore substituted for $\frac{x}{k}$ in Equations 2, 3 and 4.

CONDUCTIVITIES AND CONDUCTANCES

The method of calculating the over-all coefficient of heat transmission for a given construction is comparatively simple, but accurate values of conductivities and conductances must be used to obtain satisfactory results. In addition there are sometimes parallel heat flow paths of different resistances in the same wall, which require modification of the

formula. In such cases calculated results should be checked by test measurements.

The determination of the fundamental conductivities and conductances requires considerable skill and experience to obtain accurate results. It is recommended that thermal conductivities of homogeneous materials be determined by means of the Guarded Hot Plate [1]. For determination of conductances, a Guarded Hot Box method [2] is generally used.

Tables 1 and 2 give conductivities and conductances which are quite generally used in calculation and which have been selected from various sources. Wherever possible the properties of the material and test conditions are given. In selecting and applying heat transmission values to any construction, caution is necessary, because coefficients for the same material may differ because of variations which occur in test methods, in the materials themselves, or in the temperature of the material when tested.

Conductivity of Homogeneous Materials

Thermal conductivity is a property of a homogeneous material and of types of building materials such as lumber, brick and stone which may be considered homogeneous. Most insulating materials, except air spaces and reflective types, are of a porous nature and consist of combinations of solid matter with small air cells. The thermal conductivity of these materials will vary with density, mean temperature, size of fibers or particles, degree and extent of bond between particles, moisture present, and the arrangement of fibers or particles within the material.

The effect of density upon conductivity (at constant mean temperature) is illustrated for two fibrous materials in Fig. 1. It will be noted that for each there is an optimum density for lowest conductivity. Typical variation of conductivity with mean temperature is shown in Fig. 2.

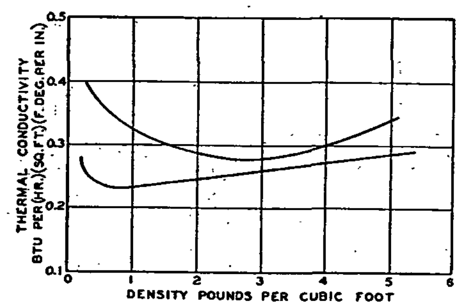

Fig. 1. Typical Variation of Thermal Conductivity with Density—for Fibrous Material

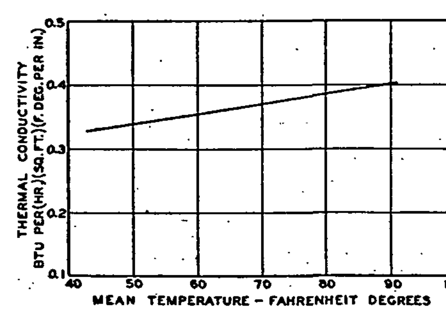

Fig. 2. Typical Variation of Thermal Conductivity with Mean Temperature