e = emissivity; the ratio of the total radiant flux emitted by a surface to that emitted by an ideal black body at the same temperature.

E = effective emissivity; the combined effect of the surface emissivities e of the boundary surfaces of an air space; the boundaries assumed to be parallel and of large dimensions as compared to the distance between them.

r = surface reflectivity; the ratio of the radiant flux reflected by an opaque surface to that falling upon it.

R = thermal resistance. Its value is obtained from the reciprocal of heat transfer as expressed by U, k, C, f or a. It is expressed in (hours) (square feet) (Fahrenheit degrees) per (Btu). For example, a wall with a U value of 0.25 would have a resistance value of $R = 1/0.25 = 4.0$. Therefore, 4 hours would be required for the transfer of one Btu for each square foot of area and each degree of temperature differential.

CALCULATING OVERALL 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.

$$R_T = R_1 + R_2 + R_3 + R_4 + \ldots + R_n \quad (1)$$

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

R_T = total resistance.

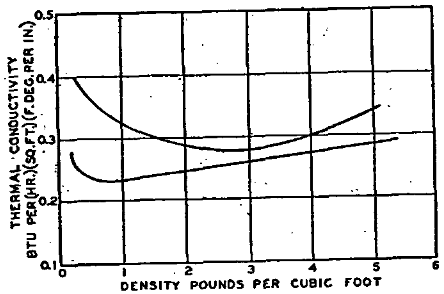

FIG. 1. TYPICAL VARIATION OF THERMAL CONDUCTIVITY WITH DENSITY—FOR FIBROUS MATERIAL

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

$$R_T = \frac{1}{f_i} + \frac{x}{k} + \frac{1}{f_o} \quad (2)$$

Then by definition, $U = 1/R_T$

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, respectively, and separated by an air space of conductance a,

$$R_T = \frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{a} + \frac{x_2}{k_2} + \frac{1}{f_o} \quad (3)$$

and $U = 1/R_T$

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 $1/C$ is therefore substituted for x/k in Equations 2 and 3.

CONDUCTIVITIES AND CONDUCTANCES

The method of calculating the overall 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, and these may necessitate modification of the formula. In such cases calculated results should be checked by test.

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 selected by the ASHAE Technical Advisory Committee on Insulation from available information. The values selected were those which in the judgment of the committee were good design values for surfaces, spaces, etc., and for the types of products marketed today.

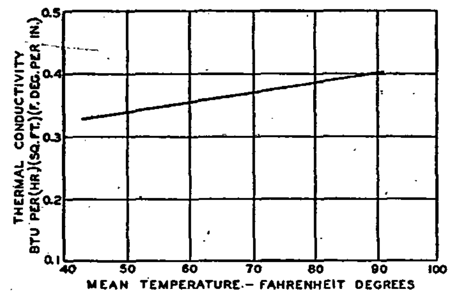

FIG. 2. TYPICAL VARIATION OF THERMAL CONDUCTIVITY WITH MEAN TEMPERATURE

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 reflective types, are of a porous nature and consist of combinations of solid matter with small voids. The thermal conductivity of these materials will vary with density, mean temperature, size of voids, 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. Typical variation of conductivity with mean temperature is shown in Fig. 2.

Thermal Conductivity of Soil

The following statements are based largely on results of a study[3] made in the *Engineering Experiment Station, University of Minnesota*, and published in *Bulletin* No. 28. Tests were made on nineteen different soils which represented a wide textural variety, including gravel, sand, sandy loam, silt loam and clay, as well as some crushed rocks and a fibrous peat. Moisture contents in tests varied from air-dried values to those greater than the optimum moisture content; densities varied from a loosely-poured