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DESIGN HEAT TRANSMISSION COEFFICIENTS

Heat Transfer Symbols; Surface Conductance; Soil Conductivity; Calculating Overall Coefficients; Overall Coefficients and Their Practical Use; Computed Coefficients of Walls, Roofs, Ceilings and Floors; Effect of Insulation; Correction for Framing; Ventilated Attics; Foundation Coefficients; Glass Coefficients; Wind Effects; Calculating Surface Temperatures; Conductivity of Industrial Insulations; Bare Surface Heat Losses; Heat Flow Calculations for Industrial Insulations

THE DESIGN of a heating, refrigerating, or air conditioning system, including selection of building insulation or sizing of piping and ducts, or the evaluation of the thermal performance of parts of the system, is based on the principles of heat transfer given in Chapter 4. The equations that are most widely used to estimate the heat transfer loads that are chargeable to the various parts will usually determine the rate of heat transfer under steady-state conditions at design temperatures. For a given part under standard conditions, this rate is a specific value, designated as U , the overall coefficient of heat transmission or thermal transmittance.

This chapter is concerned with the concepts and procedures for determining such coefficients, and includes a brief discussion of factors that may affect the values of these coefficients and the performance of thermal insulations. Coefficients may be determined by test or they may be computed from known values of the thermal conductance of the various components. The procedures used for calculating coefficients are illustrated by examples and, because it is impracticable to test all combinations of materials, tables of computed design values for the more common constructions are given.

HEAT TRANSFER SYMBOLS

U = overall coefficient of heat transmission or thermal transmittance (air-to-air); the time rate of heat flow expressed in Btu per (hour) (square foot) (Fahrenheit degree temperature difference between air on the inside and air on the outside of a wall, floor, roof, or ceiling). The term is applied to the usual combinations of materials, and also to single materials, such as window glass, and includes the surface conductance on both sides. This term is frequently called the U value.

k = thermal conductivity; the time rate of heat flow through a homogeneous material under steady-state conditions, through unit area, per unit temperature gradient in the direction perpendicular to an isothermal surface. Its unit is Btu per (hour) (square foot) (Fahrenheit degree per inch of thickness). Materials are considered homogeneous when the value of the thermal conductivity is not affected by a change in thickness or in area within the range normally used in construction. Some materials are not isotropic with respect to thermal conductivity. Care should be taken that the test method used is suitable for the particular material and gives a value of conductivity applicable to the intended use.

C = thermal conductance per unit area; thermal conductance is usually expressed in English units as Btu per (hour) (Fahrenheit degree average temperature difference between two surfaces). The heating, air-conditioning, and refrigerating engineer, however, dealing largely with compound walls with parallel surfaces, makes considerable use of the term unit conductance, or conductance per unit area, and has therefore continued the use of the term C for conductance. The average temperature is one which adequately approximates that obtained by integrating the temperature of the entire surface. The term is applied to specific materials as used, either homogeneous or heterogeneous, for the thickness or construction stated, not per inch of thickness.

f = film or surface conductance; the time rate of heat exchange by radiation, conduction, and convection of a unit area of a surface with the surroundings and the surrounding air or other fluid. Its value is expressed in Btu per (hour) (square foot of surface) (Fahrenheit degree temperature difference). Subscripts i and o are usually used to denote inside and outside surface conductances, respectively.

a = thermal conductance of an air space; the time rate of heat flow through a unit area of an air space per unit temperature difference between the boundary surfaces. Its value is expressed in Btu per (hour) (square foot of area) (Fahrenheit degree). The conductance of an air space is dependent on the temperature difference, the height, the depth, the position, character, and temperature of the boundary surfaces. Since the relationships are not linear, accurate values must be obtained by test and not by computation.

ϵ = 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 ϵ of the boundary surfaces of an air space; the boundaries are 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; the reciprocal of a heat transfer coefficient, as expressed by U , C , f , or a . Its unit is Fahrenheit degrees per Btu/(hour) (square foot). For example, a wall with a U value of 0.25 would have a resistance value of $R = 1/U = 1/0.25 = 4.0$ ru. The word ru is being used as an abbreviation for resistance unit.

other fluid. Its value is expressed in Btu per (hour) (square foot of surface) (Fahrenheit degree temperature difference). Subscripts i and o are usually used to denote inside and outside surface conductances, respectively.

a = thermal conductance of an air space; the time rate of heat flow through a unit area of an air space per unit temperature difference between the boundary surfaces. Its value is expressed in Btu per (hour) (square foot of area) (Fahrenheit degree). The conductance of an air space is dependent on the temperature difference, the height, the depth, the position, character, and temperature of the boundary surfaces. Since the relationships are not linear, accurate values must be obtained by test and not by computation.

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SURFACE CONDUCTANCE

The convection part of the surface conductance is markedly affected by air movement. This is illustrated by Fig. 1, which shows the results of tests made on 12-in. square samples of different materials at a mean temperature of 20 F, and for wind velocities up to 40 mph. These conductances include the radiation portion of the coefficient which, for the conditions of the tests, was about 0.7 Btu per (hr) (sq ft) (F deg). More recent tests on smooth surfaces show that surface length also significantly affects the convection part of conductance; the average value decreases as the surface length increases. Moreover, observations of the magnitude of low temperature radiant energy received from outdoor surroundings show that only under certain conditions may the outdoors be treated as a black body radiating at air temperature.

THERMAL CONDUCTIVITY OF SOILS

Table 1 gives thermal conductivity values of various soils. The effect of texture, moisture content and density are indicated. Detailed discussion may be found in Reference 4.

CALCULATING OVERALL COEFFICIENTS

The total resistance to heat flow through a flat ceiling, floor, or wall (or a curved surface if the curvature is small) is numerically equal to the sum of the resistances in series.

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

where R_1 , R_2 , etc., are the individual resistances of the wall components, and R_T is total resistance.

The general responsibility for this chapter is assigned to TC 2.4, Insulation and Moisture Barriers.