2. For tie rod and insulation from plane C to plane D the conductance C_2 is

$$C_2 = \frac{0.00045}{1.0} \times \frac{400}{2.5} + \frac{0.99952}{1.0} \times \frac{0.30}{2.5} = 0.072 + 0.120 = 0.192$$

3. For tie rod and concrete from plane D to plane E the conductance C_3 is

$$C_3 = \frac{0.00045}{1.0} \times \frac{400}{1.0} + \frac{0.99952}{1.0} \times \frac{12}{1.0} = 0.180 + 11.994 = 12.174$$

Series Flow. After the conductance values have been determined, the total resistance and U value can be determined as follows:

$$R_T = \frac{1}{f_i} + \frac{x_1}{k_1} + \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \frac{x_2}{k_2} + \frac{1}{f_o}$$

$$R_T = \frac{1}{1.65} + \frac{3.0}{12.0} + \frac{1}{12.174} + \frac{1}{0.192} + \frac{1}{12.174} + \frac{3.0}{12.0} + \frac{1}{6.0}$$

$$R_T = 0.606 + 0.250 + 0.0822 + 5.208 + 0.0822 + 0.250 + 0.167 = 6.727$$

$$U = \frac{1}{R_T} = \frac{1}{6.727} = 0.149 \text{ Btu per (hr) (sq ft) (F deg).}$$

The Hot Box test value, from *University of Minnesota*, for this wall, corrected for a 15 mph wind velocity, was $U = 0.150$ Btu per (hr) (sq ft) (F deg). The error between the calculated and test values would be

$$\frac{0.150 - 0.149}{0.150} \times 100 = 1 \text{ percent.}$$

If the effect of the tie rods were omitted from the calculations, the overall U value would be 0.103. Although the percentage of area occupied by the tie rods per square foot of wall area is $\frac{0.00045}{1.0} \times 100 = 0.045$ percent, the error between the calculated and test values would be

$$\frac{0.150 - 0.103}{0.150} \times 100 = 31 \text{ percent.}$$

Values Used in Calculation of U Value Tables

In making the calculations for values of U shown in Tables 7 to 19, the following conditions have been assumed:

Equilibrium or steady-state heat transfer, eliminating effects of heat capacity.

Surrounding surfaces at ambient air temperatures.

Exterior wind velocity of 15 mph for winter and 7.5 mph for summer.

Surface emissivity of ordinary building materials = 0.83.

Spaces between framing or furring not insulated. (See Table 6 for method of correcting for added insulation.)

Air spaces are ¾ in. or more in width.

Variations of conductivity with mean temperature neglected.

Corrections for framing to be made on basis of parallel heat flow through 2 × 4 in. (nominal) studs, 16 in. on centers, the framing covering 15 per cent of wall area, as indicated in Fig. 5.

Thermal resistance for gypsum board and insulating board apply equally to plain material and to those which may be decorated at the factory or on the job.

Actual thicknesses of lumber assumed to be as follows:

Nominal	Actual	Nominal	Actual
1 in. (S-2-S)	25/32 in.	3 in. (S-2-S)	2 5/8 in.
1½ in. (S-2-S)	1 5/16 in.	4 in. (S-2-S)	3 5/8 in.
2 in. (S-2-S)	1 5/8 in.	Finish flooring, (maple or oak)	¾ in.
2½ in. (S-2-S)	2 1/8 in.		

Coefficients for frame construction are corrected for the effect of framing where such correction would increase the coefficients, but not where the correction would decrease the coefficients.[11]

It should be noted that the effects of poor workmanship in construction and installation have an increasingly greater percentage effect on heat transmission as the coefficient becomes numerically smaller. Failure to meet design estimates may be caused by lack of proper attention to exact compliance with specifications. A factor of safety may be employed as a precaution when it is judged desirable.

Roof Coefficients

Computations for wood shingle roofs applied over wood stripping are based on 1 by 4 in. wood strips, spaced 2 in. apart. Values for roofs containing Spanish and French clay roofing tile are assumed the same as for slate roofs. Values for pitched roofs in Table 17 apply where the roof is over a heated attic or top floor, so that the heat passes directly through the roof structure, including any interior finish material.

Combined Ceiling and Roof Coefficients

If the attic space between the ceiling and roof is unheated and not ventilated, the combined coefficient from room air below the ceiling to exterior air can be calculated from the following formula:

$$R_T = \frac{1}{U_{ce}} + \frac{1}{nU_r} \quad (4)$$

and

$$U = 1/R_T \quad (5)$$

where U = combined coefficient to be used with ceiling area.
R_T = total resistance of ceiling and roof.
U_{ce} = coefficient of transmission of ceiling.
U_r = coefficient of transmission of roof.
n = ratio of roof area to ceiling area.

It should be noted that the overall coefficient U should be multiplied by the ceiling area to determine heat loss, and not by the roof area. Values of U_r and U_{ce} should be calculated using a value of 2.2 (the reciprocal of one-half the air space resistance) rather than 1.65 for the conductances of surfaces facing the attic, since the attic is equivalent to an air space.

If the attic contains windows, dormers and vertical wall spaces, and if their area is small compared to that of the roof, they may be considered part of the roof area. For accuracy, the sum of the coefficients of each individual section, multiplied by its percentage of the total area, should be used as U_r. Where attic wall areas are large, it is preferable to estimate the attic temperature as illustrated in Chapter 12, and calculate the heat loss through the ceiling by multiplying the value of U_{ce} for the ceiling by the difference in temperature above and below the ceiling.