nomic considerations involved in the selection of an insulating material as adapted to various building constructions. Lack of proper evaluation, or improper installation may lead to unsatisfactory results.

Computed Heat Transmission Coefficients

Computed overall heat transmission coefficients of many common types of building construction are given in Tables 6 to 20, inclusive, each coefficient being identified by a serial number, except in Tables 19 and 20. For example, the coefficient U of a brick veneer, frame wall with wood sheathing and $\frac{1}{2}$-in. of plaster on gypsum lath is 0.27 (Wall No. 28-C in Table 6) and with 2 inches of blanket or bat insulation, the coefficient would be 0.097 (No. 49-B in Table 7).

In the analysis of any wall construction for the purpose of calculating the overall coefficient of heat transmission U, it is first necessary to determine the paths of heat flow, that is, whether they are parallel or series, or a combination of both. This is in accordance with the basic laws of heat transfer which state that *in parallel flow the conductances are additive*, while *in series flow the resistances are additive*. Likewise, in order to determine the total resistance for the wall, the conductance must be known.

The importance of this analysis cannot be over-emphasized. This is especially true in wall constructions in which there are parallel paths of heat flow, and one path has a high heat transfer, while others have a low heat transfer. The method of making this calculation can best be shown by *Example 1* and Fig. 5. As this wall was tested by the hot box method at the *University of Minnesota*, a direct comparison can be made between calculated and tested values.

Example 1. Calculate the coefficient of heat transmission U for wall as shown in Fig. 5. Wall construction consists of two 4-in. concrete walls separated by a $2\frac{1}{2}$-in. space filled with insulation; $\frac{1}{4}$-in. diameter metal tie rods are imbedded a distance of 1 in. in each 4-in. concrete wall, and spaced 9 in. vertically and 12 in. horizontally. Values of k are: insulation 0.30, concrete 12.00, tie rods 400.00.

Solution. In Fig. 5 the following paths of heat flow from plane A to plane F will be noted:

1. From A to B: One path through 3 in. of concrete.
2. From B to C: Two paths, (a) through 1 in. of tie rod, and (b) through 1 in. of concrete.
3. From C to D: Two paths, (a) through $2\frac{1}{2}$ in. of tie rod, and (b) through $2\frac{1}{2}$ in. of insulation.
4. From D to E: Two paths, (a) through 1 in. of tie rod, and (b) through 1 in. of concrete.
5. From E to F: One path through 3 in. of concrete.

It will be noted that items 2 and 4 are paths of similar flow, and could be treated as one. If equilibrium or steady state heat transfer is assumed, there will exist a temperature difference between the metal tie rod and the concrete, and also between the metal tie rod and the insulating material. The rate of heat transfer between these materials is dependent upon their conductivity values and the temperature difference. As the conductivity of the metal tie rods is considerably higher than that of the concrete or insulating material, it cannot be assumed that the same rate of heat transfer takes place for all parallel paths. Likewise, an appreciable error would be made by assuming that no heat transfer takes place between the metal tie rod and the surrounding materials. Although the pattern of the isotherms is unknown, the following method of calculation does partially take into account the heat flow between the metal tie rods and its bounding materials.

Parallel Flow. The conductances through the areas of parallel heat flow may be determined as follows:

1. The area of each $\frac{1}{4}$-in. diameter tie rod is 0.00036 sq ft, and as the tie rods are spaced 9 in. vertically, and 12 in. horizontally, there will be $0.00036 \times \frac{4}{3} = 0.00048$ sq ft of tie rod to each square foot of wall area. Then from plane B to plane C, the conductance C_1 is

$$C_1 = \frac{0.00048}{1.0} \times \frac{400}{1.0} + \frac{0.99952}{1.0} \times \frac{12}{1.0} = 0.192 + 11.994 = 12.186$$

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

$$C_2 = \frac{0.00048}{1.0} \times \frac{400}{2.5} + \frac{0.99952}{1.0} \times \frac{0.30}{2.5} = 0.077 + 0.120 = 0.197$$

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

$$C_3 = \frac{0.00048}{1.0} \times \frac{400}{1.0} + \frac{0.99952}{1.0} \times \frac{12}{1.0} = 0.192 + 11.994 = 12.186$$

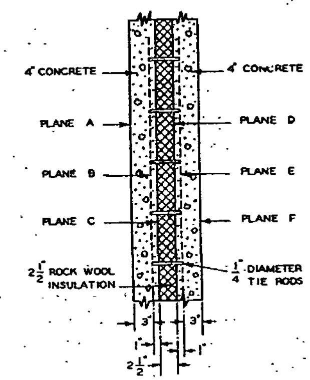

Fig. 5. Section of Concrete Wall Having Steel Tie Rods and Insulation

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

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

$$R_T = \frac{1}{1.65} + \frac{3.0}{12.0} + \frac{1}{12.186} + \frac{1}{0.197} + \frac{1}{12.186} + \frac{3.0}{12.0} + \frac{1}{6.0}$$

$$R_T = 0.606 + 0.250 + 0.0821 + 5.076 + 0.0821 + 0.250 + 0.167 = 6.513$$

$$U = \frac{1}{R_T} = \frac{1}{6.513} = 0.153 \text{ Btu per (hr) (sq ft) (F deg).}$$

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

$$\frac{0.153 - 0.150}{0.150} \times 100 = 2 \text{ percent.}$$

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