

weather side ($b = 1$; $f_o = 4$; thermal resistance = 0.28), 1 in. of insulating board, and 4 in. of concrete with no ceiling, when the temperature of the indoor air is 80 F.

The overall coefficient of heat transfer for this construction is:

$$U = \frac{1}{0.25 + 0.28 + 3.03 + 0.33 + 0.61} = 0.22 \text{ Btu per (hour) (square foot) (F deg.)}$$

If the time lag of the built-up roofing be ignored, the sum of the time lags of the individual layers is, from Table 12, (0.23 + 2.5) or 2.73 hr.

Actually, the time lag will be between 0.5 hr and 1.0 hr greater than this, so assume a time lag of 3.5 hr.

From Table 12, the homogeneous concrete roof having a time lag of 3.5 hr would have a value of λ of about 0.65; use this value for the composite roof.

From Fig. 4, λ is approximately 0.65.

With values of t_m and t_o^* found from Table 10, as in previous examples, use Equation 6 and find the maximum design instantaneous rate of heat gain as:

$$\frac{q}{A} = 0.22 [(106.4 - 80) + 0.65 (155 - 106.4)] = 13 \text{ Btu per (hr) (sq ft)}.$$

The maximum instantaneous rate of heat gain from this roof would occur at about 3:30 p.m., sun time.

Example 5. Estimate the maximum instantaneous design rate of heat gain from a south wall in Lincoln, Nebr., consisting of 4 in. of face brick ($b = 0.7$; $f_o = 4$), 4 in. of common brick, furred, with an air space (thermal resistance = 0.75), and finished on the inside with $\frac{1}{2}$ in. of plaster on metal lath (thermal resistance = 0.23); the temperature of the indoor air is constant at 80 F.

The overall coefficient of heat transfer for this construction is:

$$U = \frac{1}{0.25 + 0.44 + 0.80 + 0.75 + 0.23 + 0.61} = 0.32 \text{ Btu per (hr) (sq ft) (F deg.)}$$

From Table 12, the sum of the time lags for the face brick and the common brick is (2.4 + 2.3) or 4.7 hr. The actual time lag will be slightly greater than this, and a value of 5.5 hr will be assumed.

From Fig. 4, λ is approximately 0.45.

By interpolation in Table 11, $t_m = 99.8$ F, and $t_o^* = 123.6$ F. From Equation 6 the maximum instantaneous design rate of heat gain is:

$$\frac{q}{A} = 0.32 [(99.8 - 80) + 0.45 (123.6 - 99.8)] = 9.8 \text{ Btu per (hr) (sq ft)}.$$

The time of this heat gain is about 6:30 p.m., sun time.

Those concerned with a further study of the details of cooling-load estimates in particular relation to periodic heat flow will find much of value and interest in the reports of experimental studies of these problems.^{7, 8, 9, 10}

PRACTICAL TABLES FOR CALCULATING SOLAR HEAT GAIN THROUGH WALLS AND ROOFS

Use of Equivalent Temperature Differentials

The preceding paragraphs have explained the principles and methods used in estimating solar heat gain by use of sol-air temperature. This method is rather tedious and is not convenient for every-day use. Some new practical tables¹¹ have therefore been developed using the basic method reported by Mackey and Wright.⁷ These new tables utilize *equivalent temperature differentials* which may be multiplied by the overall heat transmission coefficient U to give directly the total heat transmission,

Btu per square foot, from solar radiation and from temperature difference between outside and room air.

These tables were prepared from sol-air data as shown in Table 13 which is approximately the same as New York data in Table 10. It is suggested that Tables 14 and 15 be used for general estimating purpose.

These analytical procedures, as well as those using Tables 10, 11 and 12 presented here, yield generally *higher* rates of heat gain than reported for Pittsburgh in early A.S.H.V.E. experimental studies. Current authoritative opinion is that the analytical calculations are to be preferred, all factors considered.

Tables 14 and 15 are based on an equation re-arranged from Equation 6 to read:

$$\frac{q}{A} = U [t_m + \lambda (t_o^* - t_m) - t_i]. \quad (7)$$

Let $t_m + \lambda (t_o^* - t_m) = t_p$, a net equivalent outdoor temperature for combined periodic and mean heat flow. Magnitudes of t_p will vary cyclically with time. Then,

$$\frac{q}{A} = U (t_p - t_i) \quad (8)$$

which is a simple form analogous to the steady state equations of Chapters 5 and 9. The rate of heat flow is obtained by multiplying the overall heat transmission coefficient of the structure by the equivalent temperature differential obtained from the tables.

Tables 14 and 15 were developed by using an outside film conductance of 4.0 and an inside film conductance of 1.65 Btu (hr) (sq ft) (F deg.). A reduction was made in the temperature differentials for roofs amounting to some 20 per cent of solar radiation as explained by Stewart.¹¹ This was to compensate for several factors, one of which is the radiant heat lost to the sky which is not included in the Mackey and Wright method. The *temperature differentials* for roofs were based on an inside film conductance of 1.65 because the charts prepared by Mackey and Wright⁷ used this value, and it was not considered practicable to repeat their work using a different film coefficient. An examination of the values given in their paper indicates that the *temperature differential* would be changed very little even if a value 1.20 were used instead of 1.65. But to obtain the heat flow rates through roofs, more accurate values will be obtained if the *overall heat transmission coefficient is calculated using 1.2 as the inside film conductance of heat transfer in summer.*

The roof coefficients of transmission for summer shown in Table 16 are based on film conductances f of 4.0 for an outside roof surface and 1.20 for an inside ceiling surface. The outside conductance 4.0 is used for summer because it corresponds to a wind velocity of approximately 7.5 mph averaged for rough and smooth surfaces, and is more representative of summer wind velocities. Also, the lower wind velocity should be used in order to be on the safe side in determining the sol-air temperature. The inside conductance 1.20 is used because the convective portion of the film conductance factor of downward heat flow from a horizontal surface is appreciably less than the winter conductance, which applies when heat is flowing upward.

Since there is little difference in *wall transmission coefficients* for summer, based on conductances of 4.0 and 1.65, and the winter coefficients, based