on the weather side will increase the time lag and decrease the instantaneous maximum rate of heat gain.

Two examples are given to show how to estimate, roughly, the instantaneous rate of heat gain through sunlit composite walls or roofs.

Example 8: Estimate the maximum instantaneous design rate of heat gain from a horizontal roof in a location having an industrial type of atmosphere. The roof is made up of black, built-up roofing on the weather side ($\alpha = 1$, $f_{\sigma o} = 4$, thermal resistance $= 0.28$), 1 in. of insulating board, and 4 in. of concrete with no ceiling. The temperature of the indoor air is 80 F.

Solution: 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 10, (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 10, 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. 2, λ is approximately 0.65.

With values of t_m and $t_e{}^*$ found from Table 9, as in previous examples, use Equation 5 and find the maximum *design instantaneous rate* of heat gain as:

$$\frac{q}{A} = 0.22[(103.4 - 80) + 0.65(151 - 103.4)] = 11.9 \text{ Btu per (hr) (sq ft).}$$

The maximum instantaneous rate of heat gain from this roof would occur at about 4:30 p.m., sun time.

Example 9: Estimate the maximum instantaneous design rate of heat gain on August 1 from a south wall in a location at 40 deg north latitude having a clear atmosphere. The wall consists of 4 in. of face brick ($\alpha_t = 0.7$; $f_{\sigma o} = 4.0$), 4 in. of common brick, furred, with an air space (thermal resistance = 0.75), and finished on the inside with $\frac{3}{4}$ in. of plaster on metal lath (thermal resistance = 0.23); the temperature of the indoor air is constant at 75 F.

Solution: 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 10, 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. 2, λ is approximately 0.45.

By interpolation in Table 9, $t_m = 89.5$ F, and $t_e{}^* = 115.4$ F. From Equation 5 the maximum instantaneous design rate of heat gain is:

$$\frac{q}{A} = 0.32[(89.5 - 75) + 0.45(115.4 - 89.5)] = 8.4 \text{ Btu per (hr) (sq ft).}$$

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.[8, 9, 11, 13, 14, 15]

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 tables[12] have therefore been developed using the basic method reported by Mackey and Wright.[11] 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 11, which

TABLE 11. SUMMER DESIGN SOL-AIR TEMPERATURES USED FOR TABLES 12 AND 13

Mean Sun Time	Sol-Air Temperature t_e Fahrenheit Degrees: Any Surface[b]	Horiz.	North	East		South		West	
Ratio[a]: $\frac{\alpha}{f_{\infty}}$	0	0.225	0	0.225	0.125	0.225	0.125	0.225	0.125
12 Midnight	77	77	77	77	77	77	77	77	77
1 AM	76	76	76	76	76	76	76	76	76
2	76	76	76	76	76	76	76	76	76
3	75	75	75	75	75	75	75	75	75
4	74	74	74	74	74	74	74	74	74
5	74	74	74	75	80	74	74	74	74
6	74	76	74	110	93	74	74	74	74
7	75	91	75	123	100	75	75	75	75
8	77	106	77	126	103	82	78	77	77
9	80	119	80	125	104	93	86	80	80
10	83	129	83	117	100	102	93	83	83
11	87	137	87	108	96	110	99	89	87
12 Noon	90	142	90	92	92	114	104	96	92
1 PM	93	144	93	93	93	115	105	110	102
2	94	140	94	95	94	111	104	124	111
3	95	132	95	95	95	104	100	135	119
4	94	120	94	94	94	99	96	141	120
5	93	107	93	93	93	95	94	139	118
6	91	96	91	91	91	91	91	125	111
7	87	90	87	87	87	88	87	103	94
8	85	85	85	85	85	85	85	85	85
9	83	83	83	83	83	83	83	83	83
10	81	81	81	81	81	81	81	81	81
11	79	79	79	79	79	79	79	79	79
24 Hr Avg t_m	83.1	100.5	83.1	93.0	88.4	89.0	86.2	93.0	88.4

[a] α = surface absorptivity, dimensionless: roof = 0.9; dark walls = 0.9, and light walls = 0.5. f_{∞} = unit convective conductance = 4.0 Btu per (hr) (F deg).

[b] values in this column are magnitudes of t_o, the outdoor air temperature.

are approximately the same as data for an industrial atmosphere in Table 9. It is suggested that Tables 12 and 13 be used for general estimating purpose.

These analytical procedures, as well as those using Tables 9 and 10 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 indicates a preference for analytical calculations.