Table 6 .... Values of the Wall Solar Azimuth, γ, for Variously Oriented Walls and Solar Altitude

Computed for 18 Deg Declination, North (August 1)

Latitude	Sun Time AM → ↓		Solar Altitude β Degrees	Azimuth Angle γ, Degrees					
				N	NE	E	SE	S	SW
30 Deg north	6 a.m.	6 p.m.	9.0	74	29	16	61		
	7	5	21.5	81	36	9	54		
	8	4	34.5	88	43	2	47	Shade	
	9	3	47.5	Shade	51	6	39	84	
	10	2	60.0		62	17	28	73	
	11	1	72.0		83	38	7	52	Shade
	12		78.0		Shade	90	45	0	45
40 Deg north	5 a.m.	7 p.m.	0.5	66	21	24	69		
	6	6	11.5	76	31	14	59		
	7	5	23.0	85	40	5	50	Shade	
	8	4	34.5	Shade	50	5	40	85	
	9	3	45.5		61	16	29	74	
	10	2	56.0		76	31	14	59	Shade
	11	1	64.5		Shade	55	10	35	80
	12		68.0			90	45	0	45
50 Deg north	5 a.m.	7 p.m.	4.5	67	22	23	68		
	6	6	13.5	78	33	12	57		
	7	5	23.5	90	45	0	45	90	
	8	4	33.0	Shade	57	12	33	78	
	9	3	42.0		70	25	20	65	
	10	2	50.0		87	42	3	48	Shade
	11	1	56.0		Shade	64	19	28	71
	12		58.0			90	45	0	45
	↑ PM →			N	NW	W	SW	S	SE

By linear interpolation, the diffuse irradiation is

$$I_d = 25 + {}^{1.6}\!/_{10}\ (33 - 25) = 26.6 \text{ Btu per (hr) (sq ft).}$$

The total solar irradiation is

$$I_t = 152.0 + 26.6 = 178.6 \text{ Btu per (hr) (sq ft).}$$

PERIODIC HEAT FLOW THROUGH WALLS AND ROOFS

The calculation of heat flow, through a structural section of a building exposed to the weather, requires consideration of the diurnal cycles of solar irradiation and air temperature. These cycles and other factors lead to a periodic variation in the instantaneous rate of heat flow into the weather surface, and a related periodic variation in the rate of heat flow into the air-conditioned space. Because of heat capacity and other factors, these heat-flow cycles are, in general, out of time phase and unequal in amplitude.

In order to calculate the rate of heat entry into the weather surface of a building, it is necessary to know:

1. The intensity of direct solar radiation striking the surface.
2. The absorptivity (or reflectivity) of the surface for direct solar radiation.
3. The intensity of diffuse or sky solar radiation striking the surface.
4. The absorptivity (or reflectivity) of the surface for diffuse or sky solar radiation.
5. The rate at which the surface emits radiation to the sky and other surroundings.
6. The rate at which the surface absorbs the low temperature radiation emitted by the sky and other surroundings by virtue of their temperatures and radiating characteristics.
7. The temperature of the surrounding air.
8. The temperature of the outer building surface.
9. The unit convective conductance for heat transfer between the air and the building surface.

The Sol-Air Temperature

The complex interrelationship of the above factors can be considerably simplified through the use of the sol-air temperature concept. The sol-air temperature t_e is the temperature of the outdoor air, which, in the absence of all radiation exchanges, would give the same rate of heat entry into the surface as would exist with the actual combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air.

The sol-air temperature data[5, 6, 10] as developed by Mackey and Wright for an industrial atmosphere were used as a basis for preparing Table 8 showing summer design sol-air temperatures. Sol-air temperatures may also be estimated from experimental observation of surface temperatures of walls and roofs which appear in the literature.[11, 12] Both analytical and experimental studies have been made on the problem[10] of heat flow through walls and roofs. 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.[10, 11, 12, 13, 14, 15] The reader may also refer to the Cooling Load chapter of THE GUIDE 1952 for the theory of heat flow through walls and roofs.

Table 7 .... Approximate Solar Declinations in Degrees

Date	Declination	Date	Declination
April 1	4.5	July 1	23.0
April 15	10.0	July 15	21.5
May 1	15.0	Aug. 1	18.0
May 15	19.0	Aug. 15	14.0
June 1	22.0	Sept. 1	8.5
June 15	23.5	Sept. 15	3.0

Table 8 ..... Summer Design Sol-Air Temperatures Used for Tables 9 and 10

Mean Sun Time	Sol-Air Temperature t_e Fahrenheit Degrees								
	Any Surface[b]	Horiz.	North	East		South		West	
Ratio[a]: $\frac{\alpha}{f_{oo}}$	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_{oo} = unit convective conductance = 4.0 Btu per (hr) (F deg).
[b] Values in this column are magnitudes of t_o, the outdoor air temperature.

PRACTICAL TABLES FOR CALCULATING SOLAR HEAT GAIN THROUGH WALLS AND ROOFS

The analytical[10] method reported by Mackey and Wright was used by Stewart[16] to obtain temperature differentials based on Table 8 and shown in Tables 9 and 10. 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 ASHAE experimental studies. Current authoritative opinion indicates a preference for analytical calculations. Thermal and physical properties of materials used in these tables are given in a paper.[16] 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 9 and 10 were developed by using an outside surface 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 percent of solar radiation as explained by Stewart.[16] 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. Experimental work by Parmelee[17] and previous work by Brunt[18] give data showing the magnitude of this radiant heat loss from a roof or wall to the sky. Temperature differentials for roofs probably would be reduced below those shown in Table 9 whenever the radiant heat lost to the sky is included in calculation of sol-air temperature. The *temperature differentials* for roofs were based on an inside surface conductance of 1.65 because the charts prepared by Mackey and Wright[10] used this value, and it was not 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. To obtain the heat-flow rates through roofs, more accurate