TABLE 4. Values of I_{D_n}, DIRECT SOLAR RADIATION RECEIVED AT NORMAL INCIDENCE AT THE EARTH'S SURFACE, AND VALUES OF I_d, DIFFUSE OR SKY SOLAR RADIATION, RECEIVED BY VARIOUSLY ORIENTED SURFACES

SOLAR ALTITUDE β, DEGREES	BTU PER (HOUR) (SQUARE FOOT)											
	FOR CLEAR ATMOSPHERES						FOR INDUSTRIAL ATMOSPHERES					
	DIRECT[a] NORMAL RADIATION	DIFFUSE OR SKY RADIATION[b,c]					DIRECT[d] NORMAL RADIATION	DIFFUSE OR SKY RADIATION[b,c]				
AM → ↓		N	E	S	W	HORIZ.		N	E	S	W	HORIZ.
5	67	6	11	4	4	7	34	4	11	5	3	9
10	123	11	20	8	7	14	58	8	22	9	7	18
15	166	14	27	11	10	19	80	11	28	13	9	24
20	197	15	32	13	12	23	103	13	36	17	12	31
25	218	16	35	15	13	26	121	16	43	21	16	38
30	235	17	36	17	15	28	136	18	47	24	18	44
35	248	17	36	19	16	30	148	19	50	27	21	48
40	258	18	36	21	17	31	158	20	50	30	23	52
45	266	19	35	23	18	32	165	21	49	31	25	55
50	273	19	33	25	19	33	172	22	47	34	27	58
60	283	21	28	27	21	34	181	22	41	37	30	63
70	289	22	23	29	23	35	188	22	34	41	34	69
80	292	—	—	—	—	—	195	—	—	—	—	—
90	294	—	—	—	—	—	200	—	—	—	—	—
↑ PM →		N	W	S	E	HORIZ.		N	W	S	E	HORIZ

[a] Moon's[4] proposed standard for sea level, 20 mm precipitable water vapor, 300 dust particles per cu cm, 2.8 mm Hg partial pressure of ozone.

[b] For 40 deg north latitude on about August 1.

[c] Based on observations by ASHAE Laboratory at Cleveland on cloudless days during which the observed normal incidence values closely approximated the normal incidence values tabulated.

[d] Derived from recommended design sol-air temperatures[4] for New York City for a horizontal surface with absorptivity of 1.0.

values of the order of those given for industrial atmospheres are usually associated with dry-bulb and wet-bulb temperatures near the design values of 95 F and 75 F (67 F dew-point). On the other hand, values approaching or exceeding those for a clear atmosphere are often encountered during Cleveland summers, but with dew-point and maximum dry-bulb temperatures 10 to 15 deg lower. Considerable judgment, therefore, is required in selecting solar intensity values for design purposes.

Data regarding the irradiation of vertical and horizontal surfaces by diffuse or sky radiation are few. Suggested design values for a 40-deg latitude on August 1 (18 deg declination, north) are given in Table 4 for the two types of atmospheres. These are based upon observations made on cloudless days in Cleveland over a period of several summers. Since less extensive data were available for industrial atmospheres, there is more uncertainty regarding these values. In both instances, the values include an unknown amount of ground reflection, which may be expected to vary with location. It should be noted that clouds which do not obscure the sun tend to *increase* diffuse radiation values. Nearby buildings may *reduce* diffuse irradiation by partial shading.

Calculation Tables

The irradiation of a surface by the sun is the product of I_{D_n}, the direct normal radiation (see Table 4), and the cosine K of the incident angle, θ. For horizontal surfaces, the cosine K equals the sine of the solar altitude.

TABLE 5. VALUES OF K, THE COSINE OF THE INCIDENT ANGLE, FOR VARIOUSLY ORIENTED WALLS AND A HORIZONTAL SURFACE

Computed for 18 Deg Declination, North (August 1)

LATITUDE	SUN TIME		COSINE K OF THE INCIDENT ANGLE						
	AM → ↓		N	NE	E	SE	S	SW	HORIZ.
30 DEG NORTH	6 a.m.	6 p.m.	0.267	0.862	0.952	0.484			0.156
	7	5	0.144	0.752	0.919	0.548			0.367
	8	4	0.030	0.604	0.824	0.561			0.566
	9	3		0.427	0.672	0.524	0.068		0.737
	10	2		0.234	0.476	0.438	0.144		0.866
	11	1		0.039	0.246	0.310	0.192		0.951
	12				0.000	0.147	0.208	0.147	0.978
40 DEG NORTH	5 a.m.	7 p.m.	0.406	0.934	0.914	0.358			0.009
	6	6	0.237	0.840	0.951	0.505			0.199
	7	5	0.079	0.705	0.919	0.594			0.391
	8	4		0.533	0.824	0.631	0.069		0.566
	9	3		0.337	0.673	0.614	0.196		0.713
	10	2		0.129	0.475	0.542	0.292		0.829
	11	1			0.246	0.424	0.354	0.076	0.903
	12				0.000	0.265	0.375	0.265	0.927
50 DEG NORTH	5 a.m.	7 p.m.	0.385	0.922	0.920	0.378			0.078
	6	6	0.199	0.813	0.951	0.532			0.233
	7	5	0.010	0.656	0.918	0.643			0.399
	8	4		0.465	0.824	0.700	0.166		0.545
	9	3		0.252	0.673	0.699	0.316		0.669
	10	2		0.030	0.475	0.642	0.433		0.766
	11	1			0.247	0.532	0.505	0.183	0.829
	12				0.000	0.375	0.530	0.375	0.848
		↑ PM →	N	NW	W	SW	S	SE	HORIZ.

For vertical walls, K is a function of the solar altitude β and the wall solar azimuth γ, thus

$$K = \cos\theta = \cos\beta\cos\gamma \qquad (1)$$

These three angles are defined in Fig. 1. Values of K are given in Table 5 and values of β and γ are given in Table 6 for 18 deg north declination (August 1).

To compute K values for orientations other than those given in Table 5, third angle ϕ, the solar azimuth, is required. In this discussion, ϕ will be measured east from south in the morning, and west from south in the afternoon. Hence, ϕ values are equal to 90 deg minus the γ values for an east or west facing wall, except when Table 6 shows the south walls to be in the shade. In this case ϕ equals $90 + \gamma$, that is, ϕ is greater than 90 deg.

The wall azimuth ψ is the angle, measured east from south to the perpendicular to the wall for walls which have an easterly component, and west from south for those having a westerly component. For example, ψ for a wall facing northeast is 135 deg.

The wall solar azimuth γ may be found according to the following schedule:

For walls facing east of south:	For walls facing west of south:
$\gamma = \phi - \psi$ a.m.	$\gamma = \phi + \psi$ a.m.
$\gamma = \phi + \psi$ p.m.	$\gamma = \phi - \psi$ p.m.

Treat negative values of γ as if they were positive. If γ is greater than 90 deg, the wall is in the shade.