representative of a *clear* summer day at sea-level elevation, and are nearly identical with values derived from suggested design sol-air temperatures for Lincoln, Nebraska.[3] Values typical of a humid industrial area derived from sol-air data for New York City[4] are also given in Table 5. Day-to-day changes in the amount of dust and water vapor in the atmosphere cause large differences in solar intensity values observed on cloudless days at a given locality. For example, it has been observed in Cleveland that 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 5 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_{Dn}, the direct normal radiation (see Table 5), and the cosine K of the incident angle, θ. For horizontal surfaces, the cosine K equals the sine of the solar altitude. 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 6 and values of β and γ are given in Table 7 for 18 deg north declination (August 1).

To compute K values for orientations other than those given in Table 6, 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 7 shows the south walls to be in the shade. In this case ϕ equals 90 + γ, 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.

TABLE 6. 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)

30 DEG NORTH LATITUDE

SUN TIME		COSINE K OF THE INCIDENT ANGLE						
AM → ↓		N	NE	E	SE	S	SW	HORIZ.
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
	↑ PM →	N	NW	W	SW	S	SE	HORIZ.

40 DEG NORTH LATITUDE

SUN TIME		COSINE K OF THE INCIDENT ANGLE						
AM → ↓		N	NE	E	SE	S	SW	HORIZ.
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
	↑ PM →	N	NW	W	SW	S	SE	HORIZ.

50 DEG NORTH LATITUDE

SUN TIME		COSINE K OF THE INCIDENT ANGLE						
AM → ↓		N	NE	E	SE	S	SW	HORIZ.
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.

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

Values of K for other seasons and latitudes may be found in the literature,[5] or may be computed from data given in *Hydrographic Office Bulletin* No. 214, Tables of Computed Altitude and Azimuth[6] and the Ephemeris of the Sun.[7] Table 8 shows the variation of solar declination during the months ordinarily requiring cooling.

Example 1: Find the solar azimuth ϕ at 6:30 p.m. at 40 deg north latitude on August 1st.

Solution: From Table 7 in the column of γ for a wall facing west ϕ for 6:00 p.m.