

Table 3 Outdoor Air Requirements*

Application	Smoking	Cfm per Person ^b		Cfm per Sq ^c Ft of Floor
		Recomm ^d	Minimum ^e	
Apartment				
Average	Some	20	10	.....
Deluxe	Some	20	10	.....
Banking space	Occasional	10	7½	.....
Barber shops	Considerable	15	10	.....
Beauty parlors	Occasional	10	7½	.....
Brokers' board rooms	Very heavy	50	20	.....
Cocktail bars		40	25	.....
Corridors (supply or exhaust)				0.25
Department stores	None	7½	5	0.05
Directors' rooms	Extreme	50	30	.....
Drug stores ^f	Considerable	10	7½	.....
Factories ^g	None	10	7½	0.10
Five and Ten Cent stores	None	7½	5	.....
Funeral parlors	None	10	7½	.....
Garages ^h				1.0
Hospitals				
Operating rooms ⁱ	None	...	...	2.0
Private rooms	None	30	25	0.33
Wards	None	20	10	.....
Hotel rooms	Heavy	30	25	0.33
Kitchens				
Restaurant				4.0
Residence				2.0
Laboratories ^j	Some	20	15	.....
Meeting rooms	Very heavy	50	30	1.25
Offices				
General	Some	15	10	.....
Private	None	25	15	0.25
Private	Considerable	30	25	0.25
Restaurants				
Cafeteria ^k	Considerable	12	10	.....
Dining room ^l	Considerable	15	12	.....
Schoolrooms ^m	None	...	...	.....
Shop, retail	None	10	7½	.....
Theater ⁿ	None	7½	5	.....
Theater ^o	Some	15	10	.....
Toilets ^p (exhaust)				2.0

* Taken from present-day practice.

† This is contaminant-free air.

‡ When minimum is used, take the larger of the two.

§ See local codes which may govern.

|| May be governed by exhaust.

¶ All outside air recommended to overcome expansion hazard of anesthetics.

See National Board of Fire Underwriters' Pamphlet No. 56.

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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_{DN} , 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. For vertical walls, K is a function of the solar altitude β and the wall solar azimuth γ , thus

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

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 + γ , that is, ϕ is greater than 90 deg.

The wall azimuth ϕ 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, ϕ for a wall facing north-east 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:

$$\gamma = \phi - \phi \text{ a.m.} \quad \gamma = \phi + \phi \text{ a.m.}$$

$$\gamma = \phi + \phi \text{ p.m.} \quad \gamma = \phi - \phi \text{ p.m.}$$

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

Values of K for other seasons and latitudes may be found in the literature,⁷ or may be computed from data given in *Hydrographic Office Bulletin No. 214, Tables of Computed Altitude and Azimuth* and the *Ephemeris of the Sun*.⁸ Table 7 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 1.

Solution: From Table 6 in the column of γ for a wall facing west ϕ for 6:00 p.m. is 90 + 14 = 104 deg, and at 7:00 p.m. is 90 + 24 = 114 deg. By interpolation, ϕ for 6:30 p.m. is 109 deg west of south (at 5:30 a.m. ϕ would be 109 deg east of south).

Example 2: Find K for a wall facing 18 deg east of south at 10:00 a.m. on August 1 at 50-deg north latitude.

Solution: The wall azimuth is 18 deg. The solar azimuth is 48 deg east (Table 6). The wall solar azimuth is 48 - 18 or 30 deg. From Table 6, β is 50 deg. Then

$$K = \cos \beta \cos \gamma = \cos 50 \times \cos 30 = 0.643 \times 0.866 = 0.557.$$

Example 3: Find K for the wall in Example 2 at 3:00 p.m.

Solution: The solar azimuth is 65 deg west. The wall solar azimuth is therefore 65 + 18 = 83 deg. The angle β is 42 deg.

$$K = \cos 42 \times \cos 83 = 0.743 \times 0.122 = 0.091.$$

Example 4: Find the total solar irradiation for the wall for the conditions of Example 2.

Solution: Use clear atmosphere solar intensities. At 50-deg altitude, the direct normal radiation is 273 Btu per (hr) (sq ft). Then,

$$I_D = K \times I_{DN} = 0.557 \times 273 = 152.0 \text{ Btu per (hr) (sq ft).}$$

Table 4 Values of I_{DN} , Direct Solar Radiation Received at Normal Incidence at the Earth's Surface, and Values of I_L , Diffuse or Sky Solar Radiation, Received by Various Oriented Surfaces

Btu per (hour) (square foot)												
Solar Altitude β , Degree	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}				
		N	E	S	W	Horiz.		N	E	S	W	Horiz.
AM → ↓												
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	149	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.

* Moon's proposed standard for sea level, 30 cm precipitable water vapor, 300 dust particles per cu cm, 2.8 mm Hg partial pressure of ozone.

† For 40 deg north latitude on about August 1.

‡ Based on observations by ASHRAE Laboratory at Cleveland on cloudless days during which the observed normal incidence values closely approximated the normal incidence values tabulated.

§ Derived from recommended design air temperatures for New York City for a horizontal surface with absorptivity of 1.0.

Table 5 Values of K , the Cosine of the Incident Angle, for Various 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			0.307
	8	4	0.030	0.604	0.824	0.561			0.506
	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
40 Deg north	12			0.000	0.147	0.208	0.208	0.147	0.978
	5 a.m.	7 p.m.	0.406	0.934	0.914	0.358			0.009
	6	6	0.237	0.840	0.851	0.505			0.199
	7	5	0.079	0.705	0.919	0.594			0.891
	8	4		0.533	0.824	0.631	0.069		0.566
	9	3		0.237	0.673	0.614	0.196		0.713
50 Deg north	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
	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	0.318		0.669
	10	2		0.030	0.475	0.642	0.433		0.756
	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.