As a further example, the infiltration of outdoor air with a high dry-bulb temperature and a high humidity ratio and the corresponding escape of room air at a lower dry-bulb temperature and a lower humidity ratio would increase both the *sensible heat load* and the *latent heat load*.

SOLAR AND SKY RADIATION AND TRANSMISSION LOSSES

Magnitude of Solar Radiation—Calculation Tables

If a plane surface were set perpendicular to the rays of the sun (*e.g.*, for *normal incidence*) outside the earth's atmosphere, it would receive solar radiation of about 420 Btu per (hr) (sq ft). A similar receiving surface on the surface of the earth would receive radiant energy at a considerably lower rate because a large part of the radiation entering the atmosphere is *scattered* in passing through the air, moisture, smoke, and dust which comprise the earth's envelope. Also, some of the atmospheric constituents, notably water vapor, carbon dioxide, and ozone, *absorb* radiant energy. This absorption and scattering cause different proportionate reductions from outer-atmosphere radiation intensity with different wavelengths. An exact analysis of these phenomena is beyond the practical purposes of air-conditioning load estimates; the important principle to remember is that the radiation reaching the surface of the earth comprises the sum of two components, namely:

I_n = The *direct radiation* (at normal incidence), which is the *transmitted fraction* of the net sun radiation received by the outer atmosphere, and

I_s = The *sky* or *diffuse* radiation coming *from the atmosphere itself* as a consequence of the scattering and absorption which give rise, in part, to a re-radiation to the earth. The diffuse radiation does not strike only at normal incidence; it strikes at *all* angles from which the sky *sees* the surface in question.

Standardized, practical-purpose values of the *direct* solar radiation incident upon a plane perpendicular to the sun's rays at the earth's surface have been proposed by P. Moon.[2] Table 5 gives these data; they are representative of a *clear* summer day at about sea-level elevation. (For industrial areas, I_n values will be slightly less than Table 5, with the greatest decrease occurring at low solar altitudes towards evening.)

Practical design data on *sky* radiation are meager. Table 6 presents a basis of estimates for *clear* summer days in terms of the direct solar radiation to sky radiation ratio.

The *solar altitude* is the angle (see Fig. 1) between the sun's rays and the horizontal.

In the usual application the receiving surface (*e.g.*, building roof or wall) will not be perpendicular to the rays of the sun. The intensity of the

TABLE 5. PROPOSED STANDARD VALUES OF I_n, DIRECT SOLAR RADIATION RECEIVED AT NORMAL INCIDENCE, AT THE EARTH'S SURFACE[a, b]

Solar Altitude, β Deg	I_n Btu per (Hr) (Sq Ft)	Solar Altitude, β Deg	I_n Btu per (Hr) (Sq Ft)	Solar Altitude, β Deg	I_n Btu per (Hr) (Sq Ft)
5	65	30	234	60	276
10	122	35	245	70	283
15	165	40	253	80	289
20	196	45	260	90	294
25	219	50	266		

[a]Calculated using the following assumptions: barometric pressure of 760 mm Hg (29.921 in.); depth of precipitable water of 20 mm (0.787 in); dust particles, by counting, 300 per cc; partial pressure of the ozone layer in the atmosphere of 2.8 mm Hg (0.110 in.). This is representative of a *clear* summer day.

[b]For sea level. As an approximate altitude correction, *add* 1 per cent for each 1000 ft altitude.

TABLE 6. APPROXIMATE RATIO OF DIRECT SOLAR RADIATION TO SKY RADIATION RECEIVED ON A HORIZONTAL SURFACE ON CLEAR DAYS IN EASTERN STATES[a]

Solar Altitude, β Deg	Ratio e	Solar Altitude, β Deg	Ratio e	Solar Altitude, β Deg	Ratio e
0	0	40	3.84	70	5.63
10	1.40	50	4.55	80	5.90
20	2.30	60	5.20	90	6.10
30	3.10				

[a]For rough estimates assume that the sky radiation on a *vertical* surface is one half of that on a horizontal surface. Sky radiation may be assumed independent of vertical-surface orientation.

direct radiation incident upon a surface, Btu per (hour) (square foot of absorbing surface), which is oriented with an angle of incidence θ for the sun's rays, is

$$I_d = KI_n, \tag{1}$$

where I_d = Intensity of incident direct radiation, Btu per (hour) (square foot of absorbing surface).

I_n = Intensity of direct radiation on a plane normal to the sun's rays, Btu per (hour) (square foot), (from Table 5).

K = Cosine of the angle of incidence θ.

The angle of incidence (see Fig. 2) is the angle between the sun's rays and the normal to the absorbing surface.

For *horizontal* surfaces the magnitude of K is determined by the time of year, the time of day (sun's position), and the latitude of the location concerned. For *vertical* surfaces, a fourth factor is needed: the *azimuth* of the surface. The azimuth (see Fig. 3) is the angle, measured clockwise, from the south to the exterior side of the wall in question.

Complete tabulated calculations are available for magnitudes of the factor K, extending over all latitudes, all azimuths, all months of the year, and all hours of the day.[3] Illustrative excerpts are given in Tables 7 and 8. Data of this type are valuable for all manner of problems involving solar radiation, and not only for cooling-load calculations.

The reader is warned that values of K from Tables 7 and 8 include only the *direct* radiation; *sky* radiation must be calculated separately and added to the direct radiation (see Table 6).

The use of Tables 5, 6, 7, and 8 requires that the relation between solar altitude and mean sun time be available in convenient form. Table 9 provides this information.

The preceding discussion has been concerned only with *incident* radiation. When radiation is incident upon a surface, part is reflected, part is absorbed, and, if the material transmits radiant energy, part is transmitted. Moreover, the building surfaces themselves *send out* radiant

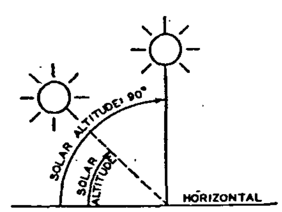

FIG. 1. DEFINITION OF SOLAR ALTITUDE

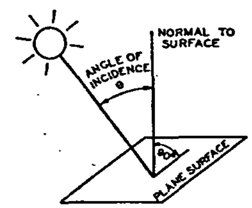

FIG. 2. DEFINITION OF ANGLE OF INCIDENCE