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

| SOLAR ALTITUDE, $\beta$ DEG | $I_n$ BTU PER (HR) (SQ FT) | SOLAR ALTITUDE, $\beta$ DEG | $I_n$ BTU PER (HR) (SQ FT) | SOLAR ALTITUDE, $\beta$ 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.

determined once the indoor and outdoor design conditions are fixed. Calculations will be discussed subsequently.

## INSTANTANEOUS HEAT LOAD

The total cooling load is frequently divided for convenience into two components, *sensible heat* and *latent heat*. While this subdivision is not imperative, past practice has found it convenient.

A gain of *sensible heat* is considered to occur when there is a direct addition of heat to the enclosure by any one or all of the mechanisms of conduction, convection, and radiation. A gain of *latent heat* is considered to occur when there is an addition of water vapor to the air of the enclosure. For example, when the humidity in an enclosure is increased by water vapor emitted by human occupants, or by water vapor resulting from a process such as cooking, the heat required to vaporize the water does *not* come from the air. Maintenance of a constant humidity ratio in a sealed enclosure requires the condensation of water vapor in the cooling apparatus at a rate equal to its rate of addition within the enclosure. The rate of heat removal from this condensing vapor would be substantially equal to the product of the rate of condensation and the latent heat of condensation; this product, expressed in Btu per hour, would be called a *latent heat* load.

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

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, $\beta$ DEG | RATIO $c$ | SOLAR ALTITUDE, $\beta$ DEG | RATIO $c$ | SOLAR ALTITUDE, $\beta$ DEG | RATIO $c$ |
|---|---|---|---|---|---|
| 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.



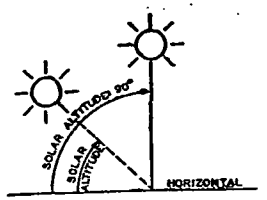



FIG. 1. DEFINITION OF SOLAR ALTITUDE

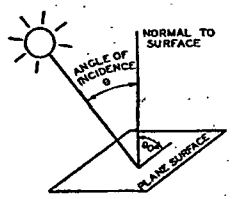



FIG. 2. DEFINITION OF ANGLE OF INCIDENCE

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 wave-lengths. 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 is the sum of $I_n$ and $I_s$.

$I_n$ = 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.[3] 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 direct radiation incident upon a surface, Btu per (hour) (square foot of absorbing surface), which is oriented with an angle of incidence $\theta$ for the sun's rays, is

$$I_d = KI_n, \qquad (1)$$

*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 $\theta$.

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