siderable reduction in heat gain, if all factors except solar intensity remain the same. Reference 22 gives heat gain values for four orientations at 40 deg north latitude on August 1 for several types of flat glass and glass block, and solar intensities typical of humid industrial atmospheres. These data show that the following approximate reductions, based on total gain for the day, can be expected: 20 percent for all types of glass and glass block in east or west facing walls; 10 percent for south facing flat glass; 5 percent for south facing glass block walls.

### Shading of Glass Areas—Design Tables

The effects and possibilities of shading should be carefully investigated whenever the heat gain from glass is a large portion of the cooling load.

Vertical glass, which is not mounted in the plane of the building surface, is partially shaded by the setback. If a vertical window of height $l$ and width $w$ be set back from the plane of the building a distance $s$, the fraction of the total area of the window which receives direct solar radiation is:

$$G_l = 1 - \frac{r_1 \tan \beta}{\cos \gamma} - r_2 \tan \gamma + \frac{r_1 r_2 \tan \beta \tan \gamma}{\cos \gamma} \qquad (5)$$

*where*

$r_1 = s/l$, $r_2 = s/w$, $\beta$ = solar altitude, and $\gamma$ is the wall solar azimuth (see Fig. 1).

Values of $\beta$ and $\gamma$ for various latitudes and August 1 are given in Table 6. Special cases not covered by the tabulated data may be solved analytically;[24] however, the design conditions chosen will yield a satisfactory approximation if used without correction for any time during the summer period.

*Example 11:* Estimate the total instantaneous rate of heat gain for a west window 3 ft wide by 5 ft high, with a setback of 6 in., for August 1 and 40 deg north latitude at 3:00 pm (sun time).

*Solution:* From Table 13, the instaneous rate of heat gain, due to transmitted direct and diffuse solar radiation, is 180 Btu per hr. From Table 6, $\beta$ is 45.5 deg and $\gamma$ is 16 deg. From Equation 5, the fraction of the total window area that is receiving direct solar radiation is:

$$G_l = 1 - \frac{0.1 \tan 45.5}{\cos 16} - 0.167 \tan 16 + \frac{0.0167 \tan 45.5 \tan 16}{\cos 16}$$

$$= 1 - 0.106 - 0.048 + 0.005 = 0.851$$

In this instance the convection and radiation heat gain is due principally to temperature difference, so that shading has but a small effect on that portion of the absorbed radiation. Hence, the factor 0.851 is applied only to the Table 13 value. Note also a small error results from the fact that the diffuse radiation is not shaded to the same extent as the direct radiation. The *total* instantaneous heat gain therefore is:

$$q = 3 \times 5\ (0.851 \times 180 + 26) = 2690 \text{ Btu per (hr)(sq ft)}$$

A window such as the one used in *Example* 11 would customarily be provided with an additional shading means for use particularly when directly sunlit. Conventional shading devices include *awnings*, *shades*, and *screens* of various types.

Experimental work conducted at the A.S.H.V.E. Research Laboratory,[24,25] and other research[26] to determine the effectiveness of various types of window shades, have been used as the basis for the recommended ratios



in column 3 of Table 24. A study of absorptivity of the shade to solar radiation and heat transfer from the shade to the outdoors and indoors, was used to determine these ratios.

There are a number of variables affecting these ratios such as color, fit, solar altitude, and angle of incidence of the solar radiation. These values, therefore, must be considered as approximate, only, and will have to be used with considerable judgment. An inside shade is effective to the extent of its reflectivity, since the portion of the solar radiation directly transmitted by the glass that is absorbed by the shade is transferred by convection to the room air, and by radiation to the solid room surfaces.

TABLE 24. EFFECT OF SHADING UPON INSTANTANEOUS SOLAR HEAT GAIN THROUGH SINGLE THICKNESS OF COMMON WINDOW GLASS

| TYPE OF SHADING | FINISH ON SIDE EXPOSED TO SUN | FRACTION OF GAIN THROUGH UNSHADED WINDOW |
|---|---|---|
| Canvas Awning | Dark | 0.25–0.35 |
| Inside Roller Shade, Fully Drawn[a] | White | 0.45 |
| Inside Roller Shade, Fully Drawn[a] | Medium color | 0.63 |
| Inside Roller Shade, Fully Drawn[a] | Dark color | 0.80 |
| Inside Roller Shade, Half Drawn[a] | White | 0.72 |
| Inside Roller Shade, Half Drawn[a] | Medium color | 0.81 |
| Inside Roller Shade, Half Drawn[a] | Dark color | 0.90 |
| Inside Venetian Blind, Slats set at 45 deg[b] | White | 0.62 |
| Inside Venetian Blind, Slats set at 45 deg[b] | Medium | 0.74 |
| Inside Venetian Blind, Slats set at 45 deg[b] | Aluminum | 0.70 |
| Inside Venetian Blind, Slats set at 45 deg[b] | Dark color | 0.86 |
| Outside Venetian Blind, Slats set at 45 deg[b] | Cream | 0.30 |
| Outside Venetian Blind, Slats set at 45 deg, extended as an awning[c] | Any color | 0.40 |
| Outside Shading Screen,[d] solar altitude 0–20 deg | Dark color | 0.75–0.43 |
| Outside Shading Screen,[d] solar altitude 20–40 deg | Dark color | 0.43–0.22 |
| Outside Shading Screen,[d] solar altitude, above 40 deg | Dark color | 0.22 |

[a] Roller shades are assumed to be opaque. Some white shades may transmit considerable solar radiation. For white translucent shades fully drawn use 0.55, and for half drawn use 0.77.

[b] Venetian blinds are fully drawn and cover window. It is assumed that the occupant will adjust slats to prevent direct rays from passing between slats.

[c] Commercial shade with wide slats.

[d] Metal slats 0.05 in. wide, spaced 0.063 in. apart, and set at 17 deg angle with horizontal. At solar altitudes below 38 deg some direct solar rays are allowed to pass between slats, and this amount becomes progressively greater at low solar altitudes.

## INSTANTANEOUS HEAT GAINS VS. INSTANTANEOUS COOLING LOADS

The difference between instantaneous heat gain and instantaneous cooling load has been mentioned previously; its practical importance is sufficient to warrant further consideration.

Fig. 4 offers a simplified schematic illustration showing how the *radiative* part of the instantaneous heat gain is first absorbed by solid objects, and is not encountered by the conditioning equipment as a cooling load until some later time, when it finally appears in the air stream entering the equipment. While it is true that some lag also is inherent in convective heat transfer and the time required to change the air in the conditioned space, this is usually of the order of a few minutes to perhaps half an hour. Heat storage in the interior furnishings and structure increases according to the proportion of the instantaneous heat gain which is in the form of