

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.<sup>3</sup> 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

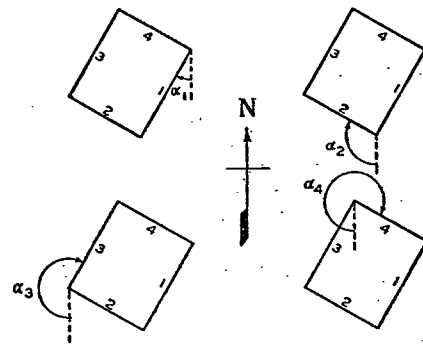


FIG. 3. DEFINITION OF AZIMUTH

The azimuth angle  $\alpha$  is always measured clockwise from the south to the exterior side of the wall in question.

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 energy to the sky and to the surroundings. The heat balance on an outer surface, for a unit time interval, may be expressed as follows:

$$\begin{aligned} \text{Heat entering outer surface} &= \left\{ \begin{array}{l} \text{Incident direct} \\ \text{solar radiation} \end{array} \right\} + \left\{ \begin{array}{l} \text{Incident sky} \\ \text{radiation} \end{array} \right\} - \left\{ \begin{array}{l} \text{Reflected direct} \\ \text{radiation} \end{array} \right\} \\ &\quad - \left\{ \begin{array}{l} \text{Reflected sky} \\ \text{radiation} \end{array} \right\} - \left\{ \begin{array}{l} \text{Radiation emitted} \\ \text{to sky by surface} \end{array} \right\} \pm \left\{ \begin{array}{l} \text{Air-to-surface} \\ \text{convection} \end{array} \right\} \quad (2) \end{aligned}$$

The convective heat transfer may be either to or from the surface, depending upon whether the air temperature is higher or lower than the surface temperature. No term has been included to represent radiation exchange with other objects in the surroundings, as this effect is not usually of significant magnitude relative to the others.

In practical calculations, the *difference* between incident and reflected radiation is computed by multiplying the incident radiation by a factor

TABLE 7. VALUES OF  $K$  FOR HORIZONTAL PLANES IN NORTH LATITUDES<sup>a</sup> DURING THE PERIOD MAY 2-AUGUST 10<sup>b</sup>

| LOCAL MEAN SUN TIME <sup>b</sup> |      | NORTH LATITUDE—DEGREES <sup>c</sup> |      |      |      |      |      |
|----------------------------------|------|-------------------------------------|------|------|------|------|------|
| A.M.                             | P.M. | 25                                  | 30   | 35   | 40   | 45   | 50   |
| 5                                | 7    |                                     |      |      | .034 | .070 | .106 |
| 6                                | 6    | .145                                | .171 | .196 | .220 | .242 | .262 |
| 7                                | 5    | .365                                | .382 | .395 | .406 | .414 | .418 |
| 8                                | 4    | .570                                | .578 | .581 | .580 | .574 | .564 |
| 9                                | 3    | .747                                | .746 | .740 | .729 | .712 | .689 |
| 10                               | 2    | .882                                | .876 | .863 | .843 | .817 | .785 |
| 11                               | 1    | .967                                | .957 | .940 | .915 | .884 | .845 |
| 12                               |      | .996                                | .985 | .966 | .940 | .906 | .866 |

<sup>a</sup> Figured for solar declination of 20 deg. <sup>b</sup> The relation between local mean sun time and civil time may be obtained from Weather Bureau offices in various localities.

called the absorptivity or the emissivity; see Table 6 and Equation 3, Chapter 5. Convection is calculated as explained in Chapters 5 and 6.

The daytime radiation emitted to the sky by a surface is not usually calculated as a separate item in practical air-conditioning work. Its effect may be roughly accounted for by an adjustment of the magnitude of the absorptivity factor for solar radiation, and this approach is often followed in making emissivity measurements for building materials exposed to the sun and sky.

When a building surface is exposed to a *clear* night sky, there is an appreciable net exchange of low temperature radiant energy from the surface to the sky, but this is not considered for the usual comfort cooling calculation. When peak load conditions occur at night, nocturnal radiation is of particular importance for glass sections. For further information, see Bruntz equation as given by Haurwitz.<sup>4</sup>

TABLE 8. VALUES OF  $K$  FOR VERTICAL PLANES IN NORTH LATITUDES DURING THE PERIOD MAY 2-AUGUST 10

| LATITUDES<br>Deg | LOCAL MEAN SUN TIME <sup>b</sup> |      | AZIMUTH SCALES FOR VALUES OF $K$ IN ORDINARY TYPE <sup>a</sup> |      |      |      |      |      |      |      |      |      |      |      |      |     |  |  |
|------------------|----------------------------------|------|----------------------------------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|-----|--|--|
|                  | A.M.                             | P.M. | 0                                                              | 15   | 30   | 45   | 60   | 75   | 90   | 105  | 120  | 135  | 150  | 165  | 180  |     |  |  |
| 30               | 5                                | 7    | .940                                                           | .831 | .666 | .455 | .213 | .049 | .298 | .589 | .788 | .874 | .908 | .984 | .940 |     |  |  |
|                  | 6                                | 6    | .908                                                           | .832 | .699 | .518 | .303 | .066 | .175 | .404 | .605 | .765 | .873 | .928 | .908 |     |  |  |
|                  | 7                                | 5    | .814                                                           | .770 | .674 | .532 | .354 | .151 | .061 | .270 | .460 | .619 | .735 | .808 | .814 |     |  |  |
|                  | 8                                | 4    | .664                                                           | .651 | .593 | .495 | .363 | .207 | .036 | .187 | .301 | .444 | .567 | .638 | .684 |     |  |  |
|                  | 9                                | 3    | .470                                                           | .482 | .462 | .410 | .331 | .229 | .111 | .016 | .139 | .264 | .388 | .485 | .470 |     |  |  |
|                  | 10                               | 2    | .243                                                           | .276 | .289 | .283 | .258 | .217 | .158 | .089 | .015 | .061 | .138 | .194 | .243 |     |  |  |
|                  | 11                               | 1    | .000                                                           | .045 | .087 | .123 | .150 | .168 | .174 | .168 | .150 | .123 | .087 | .045 | .000 |     |  |  |
| 45               | 5                                | 7    | .908                                                           | .770 | .579 | .349 | .095 | .165 | .414 | .635 | .818 | .934 | .983 | .984 | .908 |     |  |  |
|                  | 6                                | 6    | .940                                                           | .845 | .693 | .493 | .260 | .010 | .248 | .477 | .679 | .856 | .955 | .970 | .940 |     |  |  |
|                  | 7                                | 5    | .908                                                           | .859 | .751 | .592 | .393 | .167 | .070 | .308 | .514 | .691 | .821 | .895 | .908 |     |  |  |
|                  | 8                                | 4    | .814                                                           | .809 | .750 | .639 | .485 | .298 | .090 | .183 | .389 | .618 | .800 | .763 | .814 |     |  |  |
|                  | 9                                | 3    | .664                                                           | .701 | .689 | .631 | .530 | .392 | .228 | .048 | .155 | .309 | .481 | .683 | .684 |     |  |  |
|                  | 10                               | 2    | .470                                                           | .540 | .574 | .568 | .524 | .444 | .334 | .201 | .054 | .096 | .240 | .388 | .470 |     |  |  |
|                  | 11                               | 1    | .243                                                           | .338 | .411 | .455 | .468 | .449 | .400 | .323 | .225 | .111 | .011 | .131 | .243 |     |  |  |
|                  | 12                               |      | .000                                                           | .109 | .211 | .299 | .366 | .408 | .423 | .408 | .366 | .299 | .211 | .109 | .000 |     |  |  |
|                  | A.M.                             | P.M. | 360                                                            | 345  | 330  | 315  | 300  | 285  | 270  | 255  | 240  | 225  | 210  | 195  | 180  |     |  |  |
|                  |                                  |      | Time                                                           | 180  | 195  | 210  | 225  | 240  | 255  | 270  | 285  | 300  | 315  | 330  | 345  | 360 |  |  |
|                  |                                  |      | AZIMUTH SCALES FOR VALUES OF $K$ IN ITALICIZED TYPE            |      |      |      |      |      |      |      |      |      |      |      |      |     |  |  |

<sup>a</sup> Values for 30 deg latitude may be employed over the range 25 deg to 35 deg. Values for 45 deg latitude may be employed over the range 40 deg to 50 deg. Interpolation will yield values for the range 35 deg to 40 deg latitude.

<sup>b</sup> The relation between local mean sun time and civil time may be obtained from Weather Bureau offices in various localities.

<sup>c</sup> Values in ordinary type are for azimuths 0 to 180 deg. Values in italic type are for azimuths 180 to 360 deg.