The Sol-Air Temperature

A convenient way of combining the effects of solar and sky radiation, solar absorptivity, temperature, and air movement is to use the concept of sol-air temperature. The sol-air temperature, t_e, is the temperature of outdoor air which, in contact with the weather side of a material that is receiving no solar or sky radiation, would give the same rate of heat entry into that surface as would exist with the actual combination of incident solar and sky radiation and convective heat transfer.

In order to calculate the rate of heat transfer into an outside building surface for any instant of time, it is necessary to consider:

1. The intensity of direct solar radiation striking the surface.
2. The absorptivity of the surface for direct solar radiation.
3. The intensity of sky radiation striking the surface.

TABLE 9. RELATION BETWEEN LOCAL MEAN SUN TIME AND SOLAR ALTITUDE DURING THE PERIOD MAY 2–AUGUST 10 FOR NORTH LATITUDES

Local Mean Sun Time		Solar Altitude					
		North Latitude—Degrees					
A.M.	P.M.	25	30	35	40	45	50
5	7	0	0	0	2.	4.	6.
6	6	8.5	10.	11.	12.5	14.	15.
7	5	21.5	22.5	23.5	24.	24.5	24.5
8	4	35.	34.5	35.5	35.5	35.	34.5
9	3	48.5	48.	47.5	47.	45.5	43.5
10	2	62.	61.	59.5	57.5	55.	51.5
11	1	75.5	73.	70.	66.	62.	57.5
12		85.	80.	75.	70.	65.	60.

4. The absorptivity of the surface for sky radiation.
5. The rate at which the surface emits radiation to the sky.
6. The temperature of the surrounding air.
7. The temperature of the outer building surface.
8. The unit convective conductance for heat transfer between the air and the building surface. The magnitude of the convective conductance depends upon the position of the surface and the velocity of the wind or air currents.

The simultaneous consideration of all these effects is too complex for practical application, and therefore the sol-air temperature is developed as follows:

1. The equation for the rate of heat transfer into the weather side of a sunlit building material at any instant is written:

$$\left(\frac{q}{A}\right)_L = bI_t + f_o(t_o - t_L) \text{ Btu per (hour) (square foot).} \quad (3)$$

where b = absorptivity of weather side of material for incident solar and sky radiation, dimensionless.

I_t = rate of incidence of solar and sky radiation, Btu per (hour) (square foot).

t_o = outside air temperature, Fahrenheit degrees.

t_L = temperature of weather surface of the material, Fahrenheit degrees.

f_o = unit convective conductance of outside surface, Btu per (hour) (square foot) (Fahrenheit degree).

2. The sol-air temperature is defined as:

$$t_e = t_o + \frac{bI_t}{f_o} \quad (4)$$

3. Then, the instantaneous rate of heat entry into the weather side of the structure becomes:

$$\left(\frac{q}{A}\right)_L = f_o(t_e - t_L) \text{ Btu per (hour) (square foot)} \quad (5)$$

Example 1. If $t_e = 90$ F, $b = 0.7$, $I = 200$ Btu per (hour) (square foot), and $f_o = 4$, find the sol-air temperature, t_e. Substituting these values in Equation 4:

$$t_e = 90 + \frac{0.7\,(200)}{4} = 125 \text{ F.}$$

Thus the instantaneous rate of entry of heat into the weather side of this material is precisely the same as if the air temperature were 125 F with no solar and sky radiation exchange with the surface.

The preceding sol-air concept is intended for non-glass building areas. For glass surfaces a similar method could be developed, with the addition of terms to account for absorption within the material and outward radiation from the interior space. It is customary, however, to treat glass separately. (See section on Glass Areas in this chapter).

The sol-air temperature is a composite quantity, the magnitude of which is influenced by each of the variables entering its defining equation. Establishing its magnitude for design calculations is part of the broad problem of determining weather-design data. Sufficient studies have been completed, however, to produce some sol-air data of practical value.

Data of the U. S. Weather Bureau for the 10-year period from 1932 through 1941 have been studied for New York, N. Y.,[5] and Lincoln, Nebr.[6] Only simultaneous values of the air temperature and solar and sky radiation have been combined in determining design values of the sol-air temperature for various surfaces at different times of day in these localities. Since the 24-hour average of the sol-air temperature is greater in July than for any other month at both stations, the sol-air temperature at each hour in July, which was equalled or exceeded at that hour only 16 times in 310 observations, was chosen as the *design* sol-air temperature.

Summer design sol-air temperatures are given in Table 10 for New York, N. Y.; Table 11 gives similar data for Lincoln, Nebr. These data may be taken as representative for similar places in northern latitudes in the United States.

Tables 10 and 11, referring to New York for an industrial area, and to Lincoln, Nebr., for a non-industrial area, can be used to determine sol-air temperatures for other locations and conditions by applying corrections as explained in the following paragraphs (using the same symbols as given in Tables 10 and 11, but indicated by (′) for other conditions):

1. To adjust the data in Tables 10 and 11 for the variation of I_t with latitude:

a. Compute I'_t for the latitude in question from the data presented previously in this chapter. (For smoky industrial areas, decrease the direct radiation from Table 5 by 15 to 20 per cent for afternoon hours.)

b. Determine the difference $(I'_t - I_t)$ and multiply this by 0.25. Find $I_t = (f_o/b)(t_e - t_o)$ from Tables 10 and 11.

c. Add (algebraically) the difference 0.25 $(I'_t - I_t)$ to the data tabulated.