air temperature t_e is the temperature of the outdoor air, which, in the absence of all radiation exchanges, would give the same rate of heat entry into the surface as would exist with the actual combination of incident solar radiation, radiant energy exchange with the sky and other outdoor surroundings, and convective heat exchange with the outdoor air.

The sol-air temperature is developed as follows:

1. The basic heat balance equation which includes the factors listed, gives the rate of heat entry $\left(\frac{q}{A}\right)_L$ into the weather side of a sunlit building surface, and is written:

$$\left(\frac{q}{A}\right)_L = \alpha_D I_D + \alpha_d I_d + f_\infty (t_o - t_L) + \epsilon_L R_s - \epsilon_L R_L, \text{ Btu per (hr)(sq ft)} \quad (2)$$

where

α = absorptivity (dimensionless) of weather side of wall or roof for incident solar radiation. Subscripts D and d refer respectively to direct and diffuse.

I = incident solar radiation, Btu per (hour)(square foot). Subscripts D and d refer respectively to direct and diffuse.

t_o = outside air temperature, Fahrenheit degrees.

t_L = temperature of weather surface of wall or roof, Fahrenheit degrees.

f_∞ = unit convective conductance of weather surface, Btu per (hour)(square foot) (Fahrenheit degree).

R_s = low temperature radiant energy falling on surface from outdoor surroundings, Btu per (hour)(square foot of receiving surface).

ϵ_L = emissivity of surface at temperature t_L (also equals absorptivity for R_s), dimensionless.

R_L = low temperature radiant energy emitted by a black body at temperature t_L, Btu per (hour)(square foot).

2. The sol-air temperature is defined as:

$$t_e = t_o + \frac{\alpha_D I_D + \alpha_d I_d + \epsilon_L (R_s - R_L)}{f_\infty} \quad (3)$$

3. The instantaneous rate of heat entry into the weather surface of the wall or roof becomes:

$$\left(\frac{q}{A}\right)_L = f_\infty (t_e - t_L) \quad (4)$$

The term $\epsilon_L(R_s - R_L)$ is difficult to evaluate, since t_L, on which R_L depends, cannot be found until t_e and the thermal properties of the structure are known. However, t_L may be estimated from experimental observations of surface temperatures of walls and roofs which appear in the literature[8, 9] on periodic heat flow. R_L can then be found from Chapter 5, Table 5, and ϵ_L can be found from Table 3 of the same chapter. The term R_s represents the low temperature radiant energy from outdoor surroundings which falls on the surface in question (ϵ_L is the fraction absorbed). In the case of horizontal surfaces, all of this energy comes from the atmosphere of which water vapor is the principal radiating component. For horizontal surfaces, Brunt's[10] correlation of a long series of observations shows R_s to be dependent upon the dew-point temperature. For the commonly used design dew-point 67 F, his empirical equation

TABLE 9. DESIGN SOL-AIR TEMPERATURES FOR 40 NORTH LATITUDE AND 18 D DECLINATION, NORTH (AUGUST 1) FOR CLEAR AND INDUSTRIAL ATMOSPHERES

SOL-AIR TEMPERATURE, t_e, FAHRENHEIT DEGREES

Sun Time	Any[b] Surface	Clear Atmospheres					Industrial Atmospheres				
		Hor.	N	E	S	W	Hor.	N	E	S	W
$\frac{\alpha^a}{f_{cro}}$	0.0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
12	77	77	77	77	77	77	77	77	77	77	77
1 a.m.	76	76	76	76	76	76	76	76	76	76	76
2	76	76	76	76	76	76	76	76	76	76	76
3	75	75	75	75	75	75	75	75	75	75	75
4	74	74	74	74	74	74	74	74	74	74	74
5	74	74	75	76	74	74	74	75	75	74	74
6	74	85	85	112	76	76	82	80	95	77	76
7	75	102	83	132	79	78	95	81	113	80	79
8	77	119	81	137	86	81	110	82	120	86	82
9	80	136	85	134	99	85	123	85	120	96	86
10	83	149	88	124	110	88	135	88	115	105	90
11	87	160	92	111	119	92	145	92	108	113	95
12	90	165	96	96	124	96	150	95	98	117	98
1 p.m.	93	166	98	98	125	117	151	98	101	119	114
2	94	160	99	99	121	135	146	99	101	116	126
3	95	151	100	100	114	149	138	100	101	111	135
4	94	136	98	98	103	154	127	99	99	103	137
5	93	120	101	96	97	150	113	99	97	98	131
6	91	102	102	93	93	129	99	97	93	96	112
7	87	87	88	87	87	89	87	88	87	92	88
8	85	85	85	85	85	85	85	85	85	85	85
9	83	83	83	83	83	83	83	83	83	83	83
10	81	81	81	81	81	81	81	81	81	81	81
11	79	79	79	79	79	79	79	79	79	79	79
24 hr avg t_m	83.1	109.1	86.5	95.8	92.2	95.8	103.4	86.0	92.9	91.2	92.9

[a] α = surface absorptivity, dimensionless.
f_{cro} = unit surface conductance, radiation and convection combined, Btu per (hr) (sq ft) (F deg).
[b] Values in this column are magnitudes of t_o, the outdoor dry-bulb temperature.

gives R_s as 82 percent of the hemispherical radiation emitted by a *black* surface radiating at a temperature equal to that of the outdoor dry-bulb temperature. For vertical surfaces, R_s varies, since part of the energy is received from the ground, the temperature of which is influenced by solar radiation. Few data for vertical surfaces are available.

Because of the lack of data regarding R_s and the difficulty of evaluating $\epsilon_L(R_s - R_L)$, present practice in calculating sol-air temperatures is to compensate for the term by increasing f_∞. This is a rough approximation, since, during a considerable part of the night, outdoor surface temperatures are at or close to the ambient air temperatures, yet the radiation loss is of appreciable magnitude.

Example 5: If t_o = 90 F, α_t = 0.7, I_t = 200 Btu per (hr)(sq ft), f_∞ = 3.0, find the sol-air temperature for a roof when the dew-point temperature is 67 F.

Solution. Previous experience indicates that the roof temperature under these conditions will be about 120 F. ϵ_L equals 0.9. Using the tabular data of Table 4, Chapter 5, to determine R_s and R_L:

$$t_e = 90 + \frac{0.7\ (200) + 0.9\ (0.82 \times 159 - 196)}{3} = 117.0 \text{ F.}$$

Example 6: Find t_e if compensation for $\epsilon_L(R_s - R_L)$ is made by replacing f_∞ with f_{cro}, the surface conductance for radiation and convection combined, equal to 4.0.

Solution. $t_e = 90 + \frac{0.7(200)}{4} = 125.0$ F.