effective temperature for sedentary persons, as determined at the ASHAE Research Laboratory, is 67–68 ET.

As explained in Chapter 6 for so-called still air conditions, a relative humidity of approximately 50 percent is required to produce an effective temperature of 68 ET when the dry-bulb temperature is 72.5 F. However, even where provision is made for artificial humidification, the relative humidity is seldom maintained higher than 40 percent during the extremely cold weather, and where no provision is made for humidification, the relative humidity may be 20 percent or less. Consequently, in using the values listed in Table 3, consideration should be given to the actual relative humidity to be maintained, if provision is to be made for humidification. If no humidification is to be provided, the higher temperatures may not even produce comfort on cold days; if humidity is to be maintained at 50 percent, the lower temperatures will apply.

In rooms having large glass areas, when sun is not shining, or in rooms with walls having a high heat transmission coefficient, the lowered surface temperature will cause a feeling of coolness even though the air temperature in the room is at or above the temperatures indicated in the table. In rooms of this character, it is desirable to design for even higher temperatures than those listed, unless a compensating higher temperature surface is installed to offset the low-temperature surfaces.

The indoor temperatures specified in Table 3 may be used for panel heated spaces as well as for spaces heated by warm air, radiators, or convectors. It is true that warm panel surfaces tend to produce a comfortable environment at a lower room-air temperature than when warm panels are not present, but field experience in the United States has indicated that actual reductions in air temperature are slight in operation.

Temperature at Proper Level. In making the actual heat loss computations, however, for the various rooms in a building it is often necessary to modify the temperatures given in Table 3 so that the air temperature at the proper level will be used. By *air temperature at the proper level* is meant, in the case of walls, the air temperature at the mean height between floor and ceiling; in the case of glass, the air temperature at the mean height of the glass; in the case of roof or ceiling, the air temperature at the mean height of the roof or ceiling above the floor of the heated room; and in the case of floors, the air temperature at the floor level.

Temperature at Ceiling. The air temperature at the ceiling is generally higher than at the breathing level due to stratification of air resulting from the tendency of the warmer or less dense air to rise. An allowance for this fact should be made in calculating ceiling heat losses, particularly in the case of high ceilings. However, the exact allowance to be made may be somewhat difficult to determine as it depends on many factors, including (1) the type of heating system, (2) ceiling height, and (3) the indoor-outdoor temperature differential. The type of heating system is particularly important, as the temperature gradient from floor to breathing level to ceiling may depend to a large extent on whether a direct radiation, unit heater, or warm air system is used, and in the latter case, whether the air is moved mechanically or by gravity. The temperature of the heating medium is also a factor.

It is impracticable to establish rigid rules for determining the temperature difference to use in all cases. However, for residences and structures having ceiling heights under 10 ft, the comparatively small temperature differential between the breathing level and ceiling generally may be neglected without serious error. For higher ceilings, an allowance of approximately 1 percent per foot of height above the breathing level may be made for ceiling heights up to 15 ft and approximately $\frac{1}{10}$ of 1 deg per foot of height above this level. The values in Table 4 are calculated on this basis. For direct radiation and gravity warm air systems, the allowance should be increased from 50 percent to 100 percent over those given in Table 4. These rules should, however, be used with considerable discretion, as they do not apply to some types of heating systems such as those using panel and baseboard radiation, where very low temperature differences between the floor and the ceiling may exist.

Temperature at Floor Level. According to tests at the University of Illinois,[8, 9, 10] the temperature at the floor level ranged from about 2 to 6 deg below that at the breathing level, or somewhat greater than the difference between the breathing level and ceiling temperatures. Tests at the University of Wisconsin[7] indicated a somewhat smaller differential between the floor and breathing level temperatures. As a general rule, if the breathing level to ceiling temperature differential is neglected (as with ceiling heights under 10 ft), the breathing-level-to-floor differential may also be neglected, as the two are somewhat compensating, especially where both floor and ceiling losses are calculated for the same space. In other cases, the 10 ft temperature differentials in Table 4 may be used in arriving at the floor heat loss, these differentials to be subtracted from the breathing level temperature.

ATTIC TEMPERATURES

Frequently, it is necessary to estimate the attic temperature, and in such cases Equation 1 can be used for this purpose:

$$t_a = \frac{A_c U_c t_c + t_o (A_r U_r + A_w U_w + A_g U_g)}{A_c U_c + A_r U_r + A_w U_w + A_g U_g} \qquad (1)$$

where

t_a = attic temperature, Fahrenheit.
t_c = indoor temperature near top floor ceiling, Fahrenheit.
t_o = outdoor temperature, Fahrenheit degrees.
A_c = area of ceiling, square feet.
A_r = area of roof, square feet.
A_w = area of net vertical attic wall surface, square feet.
A_g = area of attic glass, square feet.
U_c = coefficient of transmission of ceiling, based on surface conductance of 2.20 (upper surface, see Chapter 9). 2.20 = reciprocal of one-half the air space resistance.
U_r = coefficient of transmission of roof, based on surface conductance of 2.20 (lower surface, see Chapter 9).
U_w = coefficient of transmission of vertical wall surface.
U_g = coefficient of transmission of glass.

Example 1. Calculate the temperature in an unheated attic, assuming the following conditions: $t_o = 70$; $t_c = 10$; $A_c = 1000$; $A_r = 1200$; $A_w = 100$; $A_g = 10$; $U_g = 0.50$; $U_c = 0.40$; $U_w = 0.30$; $U_r = 1.13$.

Solution: Substituting these values in Equation 1:

$$t_a = \frac{(1000 \times 0.40 \times 70) + 10[(1200 \times 0.50) + (100 \times 0.30) + (10 \times 1.13)]}{(1000 \times 0.40) + (1200 \times 0.50) + (100 \times 0.30) + (10 \times 1.13)}$$

$$t_a = \frac{34{,}413}{1041} = 33.1 \text{ F.}$$

Equation 1 neglects the effect of any interchange of air such as would take place through attic vents or louvers intended to preclude attic condensation. Test data[8, 9, 10] indicate reduction in temperature difference between attic air and weather is linear with attic ventilation rates between 0 and 0.5 cfm per sq ft of ceiling area. A ventilation rate of 0.5 cfm per sq ft reduces this attic-to-weather temperature difference approximately 50 percent, while a ventilation rate of 0.1 cfm per sq ft reduces this temperature difference about 10 percent. When attic ventilation meets the requirements of Table 3 in Chapter 10, 0.5 cfm per sq ft is the approximate ventilation rate under design conditions. Therefore, the attic temperature found from Equation 1 above can be reduced accordingly, depending upon the estimated ventilation rate. However, since this affects the overall heat loss of a residence with an insulated ceiling only one or two percent, it can be neglected without serious error.

Neither does this equation take into consideration such factors as heat exchange between chimney and attic or solar radiation to and from the roof. Because of these latter effects, actual attic temperatures are frequently higher than the calculated values using Equation 1. The attic temperature may be calculated in the usual manner by means of Equation 1, allowing the full value of the roof. The error resulting from this assumption will generally be considerably less than if the roof were neglected (as is sometimes the practice) and the attic temperature assumed to be the same as the outdoor temperature. When relatively large louvers are installed, as is customary in the southern states, the attic temperature is often assumed as the average between the indoor and outdoor temperatures.

For a shorter, approximate method of calculating heat losses through attics, the combined ceiling and roof coefficient may be used, as described in Chapter 9.

TEMPERATURES IN UNHEATED SPACES

The heat loss from heated rooms into unheated rooms or spaces must be based on the estimated or assumed temperature in such unheated spaces. This temperature will lie in the range between the indoor and outdoor temperatures, depending on the relative areas of the surfaces adjacent to the heated room and those exposed to the outside. If the respective surface areas adjacent to the heated room and exposed to the outdoors are approximately the same, and if the coefficients of transmission are approximately equal, the temperature in the unheated space may be assumed to be the mean of the indoor and outdoor design temperatures. If, however, the surface areas and coefficients are unequal, the temperature in the unheated space should be estimated by means of Equation 2.

$$t_u = \frac{t_i(A_1U_1 + A_2U_2 + A_3U_3 + \text{etc.}) + t_o(A_aU_a + A_bU_b + A_cU_c + \text{etc.})}{A_1U_1 + A_2U_2 + A_3U_3 + \text{etc.} + A_aU_a + A_bU_b + A_cU_c + \text{etc.}} \qquad (2)$$

where

t_u = temperature in unheated space, Fahrenheit.
t_i = indoor design temperature of heated room, Fahrenheit.
t_o = outdoor design temperature, Fahrenheit.
A_1, A_2, A_3, etc. = areas of surface of unheated space adjacent to heated space, square feet.
A_a, A_b, A_c, etc. = areas of surface of unheated space exposed to outdoors, square feet.
U_1, U_2, U_3, etc. = coefficients of transmission of surfaces of A_1, A_2, A_3, etc.
U_a, U_b, U_c, etc. = coefficients of transmission of surfaces A_a, A_b, A_c, etc.

Example 2: Calculate the temperature in an unheated space adjacent to a heated room having surface areas (A_1, A_2, and A_3) in contact therewith of 100, 120, and 140 sq ft and coefficients (U_1, U_2, and U_3) of 0.15, 0.20, and 0.25, respectively. The surface areas of the unheated space exposed to the outdoors (A_a and A_b) are respectively 100 and 140 sq ft, and the corresponding coefficients are 0.10 and 0.30. The sixth surface is on the ground and is neglected in this example. Assume $t_i = 70$ and $t_o = -10$.

Solution: Substituting in Equation 2:

$$t_u = \frac{70[(100 \times 0.15) + (120 \times 0.20) + (140 \times 0.25)] + -10[(100 \times 0.10) + (140 \times 0.30)]}{(100 \times 0.15) + (120 \times 0.20) + (140 \times 0.25) + (100 \times 0.10) + (140 \times 0.30)}$$

$$t_u = \frac{4660}{126} = 37 \text{ F.}$$

The temperatures in unheated spaces having large glass areas and having two or more surfaces exposed to the outdoors (such as sleeping porches and sun parlors), generally are assumed to be the same as outdoors.

GROUND TEMPERATURES

Ground temperatures to be assumed for estimating basement heat losses usually will differ in the case of basement walls and floors, the temperatures under the floors generally being higher that those adjacent to walls. Factors affecting these temperatures will be discussed.

Temperatures Under Basement Floors

The temperature of the ground under basement floors[11] is affected by heat sources within the basement and is not influenced by atmospheric conditions. In computing losses

Table 4 .... Approximate Temperature Differentials Between Breathing Level and Ceiling, Applicable to Certain Types of Heating Systems[a]

Ceiling Height Ft	Breathing Level Temperature (5 ft Above Floor)									
	60	65	70	72	74	76	78	80	85	90
10	3.0	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.3	4.5
11	3.6	3.9	4.2	4.3	4.4	4.6	4.7	4.8	5.1	5.4
12	4.2	4.6	4.9	5.0	5.2	5.3	5.5	5.6	6.0	6.3
13	4.8	5.2	5.6	5.8	5.9	6.1	6.2	6.4	6.8	7.2
14	5.4	5.9	6.3	6.5	6.7	6.8	7.0	7.2	7.7	8.1
15	6.0	6.5	7.0	7.2	7.4	7.6	7.8	8.0	8.5	9.0
16	6.1	6.6	7.1	7.3	7.5	7.7	7.9	8.1	8.6	9.1
17	6.2	6.7	7.2	7.4	7.6	7.8	8.0	8.2	8.7	9.2
18	6.3	6.8	7.3	7.5	7.7	7.9	8.1	8.3	8.8	9.3
19	6.4	6.9	7.4	7.6	7.8	8.0	8.2	8.4	8.9	9.4
20	6.5	7.0	7.5	7.7	7.9	8.1	8.3	8.5	9.0	9.5
25	7.0	7.5	8.0	8.2	8.4	8.6	8.8	9.0	9.5	10.0
30	7.5	8.0	8.5	8.7	8.9	9.1	9.3	9.5	10.0	10.5
35	8.0	8.5	9.0	9.2	9.4	9.6	9.8	10.0	10.5	11.0
40	8.5	9.0	9.5	9.7	9.9	10.1	10.3	10.5	11.0	11.5
45	9.0	9.5	10.0	10.2	10.4	10.6	10.8	11.0	11.5	12.0
50	9.5	10.0	10.5	10.7	10.9	11.1	11.3	11.5	12.0	12.5

[a] The figures in this table are based on an increase of 1 percent per foot of height above the breathing level (5 ft) up to 15 ft and $\frac{1}{10}$ of one degree for each foot above 15 ft. This table is generally applicable to forced air types of heating systems. For direct radiation or gravity warm air, increase values 50 percent to 100 percent.