

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 inside-outside 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 direct radiation, unit heaters or warm air 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

TABLE 3. APPROXIMATE TEMPERATURE DIFFERENTIALS BETWEEN BREATHING LEVEL AND CEILING, APPLICABLE TO CERTAIN TYPES OF HEATING SYSTEMS*

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	3.7	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

* 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 5 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.

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 3 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 3. These rules should, however, be used with considerable discretion, and 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,^{3, 4, 5, 6} 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 Wisconsin⁷ 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 3 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:

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

where

t_a = attic temperature, Fahrenheit degrees.

t_i = inside temperature near top floor ceiling, Fahrenheit degrees.

t_o = outside 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: $t_i = 70$; $t_o = 10$; $A_c = 1000$; $A_r = 1200$; $A_w = 100$; $A_g = 10$; $U_c = 0.50$; $U_r = 0.40$; $U_w = 0.30$; $U_g = 1.13$.

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. However, according to tests,⁸ such venting of attics by means of small louvers or other small openings does not appreciably reduce the attic temperature and may 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