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 6). 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 6).
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: $t_i = 70$; $t_o = 10$; $A_c = 1000$; $A_r = 1200$; $A_w = 100$; $A_g = 10$; $U_r = 0.50$; $U_c = 0.40$; $U_w = 0.30$; $U_g = 1.13$.

Solution: Substituting these values in Equation 1:

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

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

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 [5], 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. 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 outside temperature. When relatively large louvers are installed as is customary in the southern states, the attic temperature is often assumed as the average between inside and outside 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 6, page 136.

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 generally range between the inside and outside temperatures, depending on the relative areas of the surfaces adjacent to the heated room and exposed to the outside. If the respective surface areas adjacent to the heated room and exposed to the outside 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 inside and outside 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.

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

where

t_u = temperature in unheated space, Fahrenheit degrees.
t = inside design temperature of heated room, Fahrenheit degrees.
t_o = outside design temperature, Fahrenheit degrees.
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 outside, 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 outside (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 $t = 70$ and $t_o = -10$.

Solution. Substituting in Equation 2:

$$t_u = \frac{70[(100\times0.15)+(120\times0.20)+(140\times0.25)] + -10[(100\times0.10)+(140\times0.30)]}{(100\times0.15)+(120\times0.20)+(140\times0.25)+(100\times0.10)+(140\times0.30)}$$

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

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

GROUND TEMPERATURES

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

Temperatures Adjacent to Basement Walls

Ground temperatures near the surface and under open spaces vary with the climate, the season of the year and the depth below the surface. The nearer the surface (during the cold weather) the lower the temperature. Frost will penetrate to a depth of over 4 ft in some localities if not protected by snow. A thick blanket of snow will result in a higher ground temperature near the surface. Consequently ground temperatures near the surface may be higher in cold climates where the snow remains on the ground for a greater length of time than in more moderate climates where the snow melts away periodically during the winter.

Complete data for various localities are not as yet available but in estimating heat losses through vertical walls below grade, it is advisable not to assume average ground temperatures above 32 F in northern climates when estimating heat losses from heated basements. This is for the mean height of the basement wall. Since the recommended wall coefficient for basement walls in contact with the soil is only 0.10, any small variation in the assumed ground temperature will not materially affect the calculated heat loss.