Table 9. . . . Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit and Shaded Roofs

Description of Roof Construction[a]	Sun Time A.M. 8	10	12	P.M. 2	4	6	8	10	12
Light Construction Roofs—Exposed to Sun									
1" Wood[b] or 1" Wood[b] + 1" or 2" insulation	12	38	54	62	50	26	10	4	0
Medium Construction Roofs—Exposed to Sun									
2" Concrete or 2" Concrete + 1" or 2" insulation or 2" Wood[b]	6	30	48	58	50	32	14	6	2
2" Gypsum or 2" Gypsum + 1" insulation 1" Wood[b] or, 2" Wood[b] or, 2" Concrete or, 2" Gypsum + 4" rock wool in furred ceiling	0	20	40	52	54	42	20	10	6
4" Concrete or 4" Concrete with 2" insulation	0	20	38	50	52	40	22	12	6
Heavy Construction Roofs—Exposed to Sun									
6" Concrete	4	6	24	38	46	44	32	18	12
6" Concrete + 2" insulation	6	6	20	34	42	44	34	20	14
Roofs Covered with Water—Exposed to Sun									
Light construction roof with 1" water	0	4	16	22	18	14	10	2	0
Heavy construction roof with 1" water	−2	−2	−4	10	14	16	14	10	6
Any roof with 6" water	−2	0	0	6	10	10	8	4	0
Roofs with Roof Sprays—Exposed to Sun									
Light construction	0	4	12	18	16	14	10	2	0
Heavy construction	−2	−2	2	8	12	14	12	10	6
Roofs in Shade									
Light construction	−4	0	6	12	14	12	8	2	0
Medium construction	−4	−2	2	8	12	12	10	6	2
Heavy construction	−2	−2	0	4	8	10	10	8	4

[a] Includes ⅜ in. felt roofing with or without slag. May also be used for shingle roof.
[b] Nominal thickness of the wood.

Notes for Table 9

Explanation: {Total heat transmission from solar radiation and temperature difference between outdoor and room air. Btu per (hr) (sq ft) of roof area} = {Equivalent temperature differential from above table} × {Heat transmission coefficient for summer Btu per (hr) (sq ft) (F deg)}

1. *Source.* Calculated by Mackey and Wright method (see reference list) and adjusted after studying ASHRAE original test data. Estimated for about August 1 in 40 deg north latitude. (For sol-air temperatures used in calculations see Table 8.) For typical design day where the maximum outdoor temperature is 95 F and minimum temperature at night is approximately 75 F (daily range of temperature, 20 F) mean 24 hr temperature 84 F for a room temperature of 80 F. All roofs have been assumed a dark color which absorbs 90 percent of solar radiation, and reflects only 10 percent.

2. *Application.* These values may be used for all normal air conditioning estimates; usually without correction, in latitude 0 deg to 50 deg north or south when the load is calculated for the hottest weather. Note 5 explains how to adjust the temperature differential for other room and outdoor temperatures.

3. *Peaked Roofs.* If the roof is peaked and the heat gain is primarily due to solar radiation, use for the area of the roof, the area projected on a horizontal plane.

4. *Attics.* If the ceiling is insulated and if a fan is used in the attic for positive ventilation, the total temperature differential for a roof exposed to the sun may be decreased 25 percent.

5. *Corrections. For temperature difference when outdoor maximum design temperature minus room is different from 15 deg.* If the outdoor design temperature minus room temperature is different from the base of 15 deg, correct as follows: When the difference is greater (or less) than 15 deg add the excess to (or subtract the deficiency from) the above differentials.

For outdoor daily range of temperature other than 20 deg. If the daily range of temperature is less than 20 deg, add 1 deg for every 2 deg lower daily range; if the daily range is greater than 20 deg, subtract 1 deg for every 2 deg higher daily range. For example, the daily range in Miami, Florida is 12 deg or 8 deg less than 20 deg, therefore, the correction is +4 deg at all hours of the day.

Notes for Table 9. . . . Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit and Shaded Roofs (*Concluded*)

Light Colors. Credit should not be taken for light colored roofs except where the permanence of the light color is established by experience, as in rural areas or where there is little smoke. When the exterior surface of roof exposed to the sun is a light color, such as white or aluminum (which absorb approximately 50 percent and reflect 50 percent of the solar radiation) add to the temperature differential for roof in shade 55 percent of the difference between the roof in sun and roof in shade. When the roof exposed to the sun is a medium color such as light grey, blue or green, or bright red, add 80 percent of this difference.

For solar transmission in latitudes other than 40 deg north, and in other months. The table values of temperature differentials will be approximately correct for a roof in the following months:

North Latitude: Latitude (deg)	Months	South Latitude: Latitude (deg)	Months
0	All months	0	All months
10	All months	10	All months
20	All months except Nov, Dec, Jan	20	All months except May, June, July
30	Mar. Apr, May, June, July, Aug, Sept	30	Sept, Oct, Nov, Dec, Jan, Feb, Mar
40	April, May, June, July, Aug	40	Oct, Nov, Dec, Jan, Feb
50	May, June, July	50	Nov, Dec, Jan

For other months, the total temperature differential (t_x) may be approximated by the use of the following formula:

$$t_x = t_s + \frac{I_x}{I_y}(t_e - t_s)$$

where

t_s = temperature differential for the same roof in shade for desired time of day; obtained from Table 9.

I_y = maximum solar transmission through glass, Btu per (hr) (sq ft) for flat skylight in Aug., 40 deg north latitude (*Note:* this is maximum value irrespective of time).

I_x = same as I_y except use the maximum value for flat skylight, for month, and latitude desired for t_x.

t_e = temperature differential for particular roof exposed to sun for the desired time of day from Table 9.

(*Note that this makes adjustment only for solar radiation and that there may be additional correction for outdoor temperature.*)

values will be obtained if the *overall heat transmission coefficient is calculated using* 1.2 as the inside film conductance for summer.

The roof coefficients of transmission for summer shown in Table 11 are based on surface conductances $f_{o,s}$ of 4.0 for an outside roof surface and 1.20 for an inside ceiling surface. The outside conductance 4.0 is used for summer because it corresponds to a wind velocity of approximately 7.5 mph averaged for rough and smooth surfaces, and is more representative of summer wind velocities. Also, the lower wind velocity should be used in order to be on the safe side in determining the sol-air temperature. The inside conductance 1.20 is used because the convective portion of the film conductance for downward heat flow from a horizontal surface is appreciably less than the winter conductance for heat flowing upward.

Since there is little difference in *wall transmission coefficients* for summer, based on the conductances of 4.0 and 1.65, and the winter coefficients, based on 6.0 and 1.65, it is recommended that the overall coefficient U, *for walls*, be taken directly from the tables in Chapter 9 in which they are based on an outside film conductance of 6.0, corresponding to a 15 mph wind velocity.

Advantages of Equivalent Temperature Differential Method

The advantages of the *equivalent* temperature differential method of determining the total heat transmission are given in following paragraphs, and are apparent from *Examples 5* to 7.

1. The total sensible heat flow is obtained by multiplying the overall heat transmission coefficient U, and the equivalent temperature differential indicated in Tables 9 and 10.

2. The temperature differentials listed for a few representative types of construction may be used on all classes of walls and roofs, even though the overall heat transmission coefficient is different, provided the structure has thermal and physical properties similar to one of those listed in Tables 9 and 10.

3. Adjustments can be made, according to instructions given in the footnotes, for room and outdoor conditions different from those on which the tables are based.

Examples of Use of Equivalent Temperature Tables

Example 5: Given: A roof is constructed of 6 in. of stone concrete with 2 in. of insulating board and tar felt roofing ⅜ in. thick, and is exposed to the sun. The location is the central part of the United States. Find the rate of heat flow into building at 2:00 p.m. during July for an outdoor design temperature 95 F, and an indoor temperature 80 F.

Solution: From Table 9 in 2 p.m. column for 6-in. concrete plus 2-in. insulation find the total equivalent temperature differential 34 deg. The overall heat transmission coefficient for summer is taken from Table 11 and is found to be 0.13. The heat-flow rate equals 34 × 0.13 = 4.42 Btu per (hr) (sq ft).

Example 6: For the conditions of *Example 5*, find the rate of heat flow into building at 2:00 p.m. during July for design temperatures of 105 F (outdoor) and 78 F (indoor). Daily range of temperature 30 deg, i.e., outdoor temperature minimum of 75 F which occurs at 4:00 or 5:00 a.m.; this being 30 deg less than the maximum.

Solution: Make correction in equivalent temperature differential in accordance with Note 5 in Table 9 as follows:

The correction for 27-deg design temperature difference is $(27 - 15) = +12$.

The correction for 30-deg daily range is $\left(-\frac{30 - 20}{2}\right) = -5$.

Net total correction is $+12 - 5 = +7$.

The heat-flow rate at 2:00 p.m. is $(34 + 7) \times 0.13 = 5.32$ Btu per (hr) (sq ft).

A method of determining *heat-flow rates*, when structure is not given in Tables 9 or 10, is illustrated in *Example 7*.

Example 7: A 4-in. stone concrete roof covered with an average depth of 4 in. of cinder concrete ($k = 4.9$), on which is placed a ⅜-in. thick felt roof with ½-in. pitch and slag.