practical value to the heating and ventilating engineer. Approximate results may be obtained by adding the number of degrees given in Table 2 to the outside design dry-bulb temperature in calculating the heat transmission through a wall or roof which may be exposed to the sun for an appreciable length of time. Table 2 was obtained from a study of the data in A.S.H.V.E. research papers on solar radiation[1, 3]. Black and aluminum painted surfaces represent the extremes which are likely to occur. For other types of surfaces, values intermediate between those given in the table can be used.

Time Lag

The calculation of heat transmitted through walls and roofs does not take into consideration the heat capacity of the structure and the consequent time lag in the transmission of heat. In the thick walls used in modern office buildings the time lag may amount to 10 hours or more[4]. Thus in many cases the wall transmission cannot be added directly to the cooling load from other sources because the peak of the wall transmission load may not coincide with the peak of the total cooling load and may even occur after the cooling system has been shut down for the day. The data in Table 3 were taken from A.S.H.V.E. research papers[3, 4] and while they result principally from a study of experimental slabs, they give an idea of the time lag to be expected in various structures.

Table 3. Time Lag in Transmission of Solar Radiation through Walls and Roofs

Type and Thickness of Wall or Roof	Time Lag, Hours
2-in. pine	1½
6-in. concrete	3
4-in. gypsum	2½
3-in. concrete and 1-in. cork	2
2-in. iron and cork (equivalent to ¾-in. concrete and 2.15-in. cork)	2½
4-in. iron and cork (equivalent to 5½-in. concrete and 1.94-in. cork)	7¼
8-in. iron and cork (equivalent to 16-in. concrete and 1.53-in. cork)	19
22-in. brick and tile wall	10

In intermittently cooled buildings the cooling capacity must be sufficient to care for the load imposed by the necessity to cool down the furnishings and the material of the interior construction to the point of maintained temperatures.

Transmission of Solar Radiation Through Glass

In considering the transmission through glass several factors must be considered. As the sun's rays impinge against a pane of glass, most of the radiation passes through to the other side, a small amount is reflected, and the balance is absorbed by the glass. The amount absorbed depends upon the character and thickness of the glass and the angle between the sun's rays and the glass. The temperature of the glass is raised by the absorbed

[3]Heat Transmission as Influenced by Heat Capacity and Solar Radiation, by F. C. Houghten, J. L. Blackshaw, E. M. Pugh, and Paul McDermott (A.S.H.V.E. Transactions, Vol. 38, 1932).

[4]Field Studies of Office Building Cooling, by J. H. Walker, S. S. Sanford, and E. P. Wells (A.S.H.V.E. Transactions, Vol. 38, 1932).

heat and this heat is then delivered to the air on the two sides of the glass in proportion to the difference between glass and air temperatures.

The A.S.H.V.E. tests indicated that a single pane of double strength glass 0.127 in. thick absorbs approximately 11 per cent of the solar radiation passing through it when the impingement is normal. For smaller angles of impingement, the glass retards percentages of the total radiant energy approximately in proportion to the sine of the angle. Other experiments[4] indicate a glass absorption of 16.7 per cent for one pane of glass and 37.5 per cent for two ¼-in. panes separated by a 1¾-in. air space.

The amount of solar radiation delivered to an unshaded glass surface may be obtained from the curves in Fig. 1. For surfaces other than those given, the solar radiation incident to the glass must be calculated. Hendrickson and Walker[5] have shown how this may be done if the wall faces some direction other than east, west, or south. They have also shown how to calculate the net glass area on which the solar radiation impinges when the glass is partly shaded by the frame or wall. The values from Fig. 1 must be used only for the net glass area on which the sun shines. Tests at the A.S.H.V.E. Research Laboratory[6] have determined the percentages of heat from solar radiation actually delivered to a room with bare windows and with various types of outdoor and indoor shading. The data in Table 4 are taken from these tests.

Table 4. Solar Radiation Transmitted through Bare and Shaded Windows

Type of Appurtenance	Per Cent Delivered to Room
Bare window glass	97
Canvas awning	28
Inside shade, fully drawn	45
Inside shade, one-half drawn	68
Inside Venetian blind, fully covering window	58
Outside Venetian blind, fully covering window	22

The percentage figures in this table were obtained by dividing the total amount of heat actually entering through the shaded window by the total amount of heat calculated to enter through a bare window (solar radiation plus glass transmission based on observed outside glass temperature). For bare windows on which the sun shines, the transmission of heat from outside air to glass is small or negative as the glass temperature is raised by the solar radiation absorbed. Therefore, in calculating the total heat gain through windows on the sunny sides of buildings, it is sufficiently accurate to figure the total cooling load due to the window, as the solar radiation times the proper factor from Table 4, and to neglect the heat transmission through the glass caused by the difference between the temperatures of the inside and outside air. Another reason for neglecting this glass transmission load is that the curves in Fig. 1 were

[5]Summer Cooling for Comfort as Affected by Solar Radiation, by G. A. Hendrickson and J. H. Walker, *Heating and Ventilating*, November, 1932, and The Determination of Sun Effect on Summer Cooling Loads, by G. A. Hendrickson and J. H. Walker, *Heating and Ventilating*, June, 1933.

[6]Studies of Solar Radiation Through Bare and Shaded Windows, by F. C. Houghten, Carl Gutberlet, and J. L. Blackshaw (A.S.H.V.E. Transactions, Vol. 40, 1934).