as given in Weather Bureau reports usually occur only from 1 per cent to 4 per cent of the time, and they are therefore of such short duration that it is not practical to design a cooling system covering this range. The temperatures shown in Table 1 have been chosen after extensive study of the Weather Bureau records and are temperatures that are not exceeded more than 5 to 8 per cent of the time during June, July, August, and September for an average year.

Solar Radiation

Fig. 1 shows the total amount of solar energy in Btu per square foot per hour received during the day by a surface normal to the rays of the sun; by a horizontal surface, and by east, west, and south walls. The curves are drawn from A.S.H.V.E. Laboratory data obtained by pyrheliometer, are based on sun time, and are for a perfectly clear day on August 1 at a north latitude of 40 deg. Data from these curves may be used with little error for most United States latitudes and for all of the hotter months of the year.

The absorption of solar radiation by a surface depends upon the character of the surface and the angle of the surface with respect to the direction of the radiation. The heat absorption by a black oilcloth surface perpendicular to the sun's rays was found to be as high as 273 Btu per square foot per hour, based on tests conducted by the A.S.H.V.E. Research Laboratory in Pittsburgh[1]. Lamp black, red brick dust, and aluminum bronze painted surfaces perpendicular to the sun's rays showed, respectively, 94.0, 63.4, and 28.2 per cent as high a rate of absorption as the black oilcloth.

TABLE 2. ALLOWANCE FOR SOLAR RADIATION ON ROOFS AND WALLS

APPROXIMATE NUMBER OF DEGREES TO ADD TO DRY-BULB TEMPERATURE FOR DIFFERENT TYPES OF SURFACES

TYPE OF SURFACE	BLACK	RED BRICK OR TILE	ALUMINUM PAINT
Roof, horizontal	45	30	15
East or west wall	30	20	10
South wall	15	10	5

Solar radiation is an important factor in the mechanism of heat flow into buildings. Research conducted at the A.S.H.V.E. Research Laboratory[2] has shown that a large error may be introduced into the calculations by failure to consider the periodical character of heat flow resulting from the diurnal movement of the sun and the heat capacity of the structure which determine the timing and magnitude of the heat wave flowing through the wall into a building on a hot, sunny day.

[1]Absorption of Solar Radiation in Relation to the Temperature, Color, Angle, and Other Characteristics of the Absorbing Surface, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930).

[2]For further information on this subject see following A.S.H.V.E. research papers: Coefficients of Heat Transfer as Measured under Natural Weather Conditions, by F. C. Houghten and C. G. F. Zobel (A.S.H.V.E. TRANSACTIONS, Vol. 34, 1928); Absorption of Solar Radiation in Its Relation to the Temperature, Color, Angle and Other Characteristics of the Absorbing Surface, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 36, 1930); *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).

Unfortunately, the calculations for the transmission of heat from solar radiation through building walls are too complicated to be of much 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 an excess cooling capacity must be provided to care for the additional 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

[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 (A.S.H.V.E. Research Paper), by J. H. Walker, S. S. Sanford, and E. P. Wells (A.S.H.V.E. TRANSACTIONS, Vol. 38, 1932).