

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 based on the maximum intensity of solar radiation observed at the A.S.H.V.E. Laboratory during a three-year study, so results based on these curves will be amply high. It will be noted that Table 4 gives the amount of heat delivered through the window as 97 per cent of the solar radiation, which is greater than is indicated by the figures for absorption in the preceding paragraph. The explanation is that much of the radiation absorbed by the glass is delivered to the room.

Fig. 1 shows that the maximum solar intensity on any surface is of limited duration. In the case of windows the total energy impinging on the glass before and after the time of maximum intensity is further reduced by increased shading of the glass from the frame, or wall. The cooling load due to solar radiation therefore does not have to be figured as a steady load. Another point which should be noted is that the maximum solar radiation load on an east wall occurs early in the morning when the outside temperature is low.

In a recent paper by the A.S.H.V.E. Research Laboratory⁷ it was shown that ordinary double strength window glass transmits no measurable amount of energy radiated from a source at 500 F or lower; that it transmits only 6.0 and 12.3 per cent of the total radiation from surfaces at 700 F and 1000 F, respectively; and that it transmits 65.7 per cent of the radiation from an arc lamp, 76.3 per cent of the radiation from an incandescent tungsten lamp, and 89.9 per cent of the radiation from the sun. Thus, glass windows in a room constitute heat traps, which allow rather free transmission of radiant energy into the room from the sun or warm objects in it, but do not allow the transmission of re-radiated heat from these same objects.

Some recent tests⁴ indicated that sunshine through window glass is the most important factor to contend with in the cooling of an office building. At times it was shown to account for as much as 75 per cent of the total cooling necessary. Because of the importance of the sunshine load, cooling systems should be zoned so that the side of the building on which the sun is shining can be controlled separately from the other sides of the building. If buildings are provided with awnings so that the window glass is shielded from sunshine, the amount of cooling required will be reduced and there will also be less difference in the cooling requirements of different sides of the building. The total cooling load for a building exposed to the sun on more than one side is of course less than the sum of the maximum cooling loads in the individual rooms since the maximum solar radiation load on the different sides occurs at different times.

Heat and Moisture Leakage

An allowance must be made for the heat and moisture in the outside air introduced for ventilating purposes or entering the building through cracks, crevices, doors, and other places where infiltration might occur.

⁷Radiation of Energy Through Glass, by J. L. Blackshaw and F. C. Houghten (A.S.H.V.E. Journal, Section, Heating, Piping and Air Conditioning, October, 1933).

The volume of air entering due to infiltration may be estimated from data given in Chapter 6, and information on the amount of outside air required for ventilation will be found in Chapter 2.

The heat gain resulting from the outside air introduced may be estimated from the following formula:

$$H_i = Qd_o(\theta_o - \theta) \quad (2)$$

where

- H_i = heat to be removed from outside air entering the building, Btu per hour.
- Q = volume of outside air entering the building, cubic feet per hour.
- d_o = density of outside air, pounds of dry air per cubic foot of outside air, at the temperature t_o .
- θ_o = heat content of mixture of outside dry air (at temperature t_o) and water vapor, Btu per pound of dry air.
- θ = heat content of mixture of inside dry air (at temperature t) and water vapor, Btu per pound of dry air.

Heat and Moisture Sources

Figs. 6 to 9, Chapter 2, show the heat and moisture given off by human beings under various conditions of activity. For average conditions where a person is normally at rest, as in a theater, or doing very light work, as in a restaurant or residence, the total amount of heat given off will average about 400 Btu per hour. Part of this is latent heat due to the evaporation of 700 to 1200 grains of moisture per hour. Examples illustrating heat and moisture loss calculations for human beings are given in Chapter 2.

TABLE 5. HEAT GAIN DUE TO VARIOUS DEVICES, BTU PER HOUR

Lights and electric appliances.....	3,415 per kilowatt
Motors, 1/10 hp.....	255
Motors, 1 hp.....	2,546
Restaurant coffee urns, 10-gal capacity.....	16,000
Dish warmers per 10 sq ft of shelf.....	6,000
Restaurant range—4 burners and oven.....	100,000
Residence gas range.....	
Giant burner.....	12,000
Medium burner.....	9,000
Oven.....	1,000 per cu ft of space
Pilot.....	250
Electric Range.....	
Small burner, 100 to 1350 watts.....	3,415 to 4,600
Large burner, 1700 to 2200 watts.....	5,800 to 7,500
Oven, 2000 to 3000 watts.....	6,830 to 10,245
Appliance connection, 660 watts.....	2,250
Warming compartment, 300 watts.....	1,025

All sources of heat must of course be considered in designing the conditioning system. The heat gain due to various devices is given in Table 5. An example of cooling load calculation is given in Chapter 9.

PROBLEMS IN PRACTICE

1. a. What should be the dry- and wet-bulb temperatures in a restaurant when the outdoor dry-bulb temperature is 95 F?
- b. What is the most desirable indoor dry-bulb temperature and relative humidity in an office building in summer?
- c. Dry-bulb, 80 F; wet-bulb, 65 F. (Table 2, Chapter 2.)
- d. 76.5 F and 50 per cent relative humidity. (Fig. 3, Chapter 2.)