Convective Heat Transfer at Exterior Surface Of Building

Under winter conditions as the outdoor temperature falls the glass temperature falls. This increases the natural convection coefficient, which depends upon Δt, and decreases the radiation coefficient, which is a function of mean temperature (see *Fig. 20*). In summer, *both* increase as the outdoor temperature increases. *For purposes of simplicity in estimating the film coefficients*, it will be assumed that there is no temperature gradient across the glass. The error involved in this assumption is negligible in its effect on either the film coefficient or the overall coefficient. The actual solution requires a plotting of curves, which will not be shown here.

Computations for Single Glass

For single glass 4 ft long, 15 mph wind at 0 F, indoor temperature 70 F, glass 1/8 in. thick, conductivity 6.0 Btu per (hr) (sq ft) (F deg per in.):

The outdoor coefficient may be obtained from Equation 6:

$$(N_{Nu})(N_{Pr})^{2/3} = \frac{0.2275}{(\log N_{Re})^{2.58}}$$

$$\left(\frac{h}{c\rho V}\right)\left(\frac{c\mu}{k}\right)^{2/3} = \frac{0.2275}{\left(\log \frac{\rho V L}{\mu}\right)^{2.58}}$$

whence

$$h_{co} = \frac{0.243 \times 0.0863 \times 5280 \times 15}{(0.74)^{2/3}} \times \frac{0.228}{\left(\frac{\log 0.0863 \times 5280 \times 15 \times 4}{10.98 \times 10^{-6} \times 3600}\right)^{2.58}}$$

$$= 4.81$$

Curve plotting $(\Delta t)(h) = Q$ vs glass temperature shows that the glass temperature is about 16 F. The mean temperature with respect to the outdoors is 8 F, giving a radiation coefficient of 0.70 (Fig. 20). The total outdoor coefficient, h_o, is therefore, 0.93 × 0.70 + 4.81 = 5.46 Btu per (hr) (sq ft) (F deg).

The indoor Δt is (70 − 16) or 54 F and the indoor mean temperature is 44 F. The respective convective and radiation coefficients are 0.73 and 0.82 giving a total indoor coefficient, h_i, of 1.55. The overall coefficient U, for the window is:

$$\frac{1}{U} = \frac{1}{h_o} + \frac{l}{k} + \frac{1}{h_i} = \frac{1}{1.55} + \frac{0.125}{6} + \frac{1}{5.46} = 0.645 + 0.021 + 0.183 = 0.849$$

and

$$U = 1 \div 0.849 = 1.18 \text{ Btu per (hr) (sq ft) (F deg)}.$$

As a check on heat flow through each film:

16 F drop outdoor air to glass × 5.46 = 87.5 Btu per (hr) (sq ft)

54 F drop glass to indoor air × 1.55 = 83.8 Btu per (hr) (sq ft).

This is a satisfactorily close check. It was found that *for the 20 deg differential* h_i varied but little from a value of 1.55. However, for summer conditions of 90 F outdoors and 80 F indoors, h_i = 1.47, h_o = 5.30, and U = 1.12 for the same length of surface and 15 mph.

Computations for Double Glass

The same general procedure was followed with respect to double glass. The differential between the outer glass and the outdoors was found to be about 10 F deg; between the two sheets of glass, about 35 F deg; and between the inner glass and the indoor air, about 25 F deg. The film coefficients respectively, for a 4-ft surface length, are 5.44, 1.13, and 1.48 Btu per (hr) (sq ft) (F deg). The overall coefficient is:

$$\frac{1}{U} = \frac{1}{5.44} + \frac{1}{1.13} + \frac{2 \times 0.125}{6} + \frac{1}{1.48} = 1 + 1.780$$

whence

$$U = 0.56 \text{ Btu per (hr) (sq ft) (F deg)}.$$

The same method has been used to compute the overall coefficients for triple glass and for the example of the railroad car.

No. 1317

INFLUENCE OF GASEOUS RADIATION IN PANEL HEATING†

By F. W. Hutchinson*, Lafayette, Ind.

Introduction

The exchange of radiant energy between surfaces is usually evaluated on the assumption that the intervening medium is non-absorbing. Actually, both absorption and emission of radiation occur in room air due to the presence of carbon dioxide and of water vapor. The influence of the carbon dioxide is small and that of the water vapor is widely variable, but the combined effect of gaseous radiation in an average room and under average conditions will be shown to be of the order of 10 percent. This value, in itself, is not insignificant, but when metal surfaced reflective materials are considered for use in panel heating, the importance of gaseous radiation is enormously magnified and, as will also be shown, becomes the controlling factor of design for reflective heating systems.

The great practical importance of gaseous radiation in connection with the use of reflective surfaces can be readily visualized by considering the boundary case of an occupant losing heat by radiation to the surfaces of a room 15 ft × 15 ft × 9 ft. If the room surfaces were thermally black, radiant loss from the occupant to his surroundings would occur at the maximum rate of approximately 160 Btu per hr. If the room surfaces were perfect reflectors and if no gaseous radiation were involved, the radiant loss from the occupant would be zero. Thus, it would appear that perfect reflectors would greatly decrease room heating requirements. By equations which are developed later in this paper, it can be shown, however, that the effect of gaseous radiant absorption in such a room would be to dissipate more than 80 percent of the radiant energy emitted by the occupant; thus, even a perfectly reflecting surrounding (which cannot exist in practice) would conserve only 20 percent of body radiant heat

†An analytical paper resulting from a research project on comfort conducted at Purdue University under a grant from the Minneapolis-Honeywell Regulator Co.; this paper was prepared in cooperation with the Housing Research Division of the Purdue Research Foundation: G. Stanley Meikle, Research Director of the Foundation. Carl F. Boester, Housing Executive.

*Professor of Mechanical Engineering, Purdue University, Lafayette, Ind. Member of A.S.H.V.E.

Presented at the Semi-Annual Meeting of the American Society of Heating and Ventilating Engineers, Coronado, Calif., June 1947.