

emissivity of materials, etc. It is generally agreed, however, that the equation is accurate to within 10 percent when used in conventional heating and cooling calculations. Tests⁴ conducted in the ASHAE Environment Laboratory⁴ showed that the value of the constant of Equation 3 was 0.152 in the test room. The design information in this chapter is based on that value of the constant.

Radiation exchange calculated from Equation 3 is given in Fig. 9. The values apply to either ceiling, floor, or wall panel radiation output.

Convection Transfer

Convection values of heat transfer are not easily established. Convection in a panel heated space is usually considered to be of the *natural* type, that is, air motion is generated by the warming (by conduction) of the boundary layer of air which starts moving as soon as its temperature exceeds that of the surrounding air. In practice, however, there are many factors which interfere with or affect *natural* convection. The configuration of the room and the space connected to it and the variation in temperature throughout the two spaces determine the *natural* convection. Infiltration, ventilation, and the movement of persons may serve to introduce some *forced* convection which can disturb the *natural* process.

The laboratory approach has been to measure the *natural* convection in a bare, box-like room which is sealed against infiltration and in which all surfaces, except the heated panel, are at one uniform temperature. Convection was also measured with varying amounts of infiltration and a correction determined for use in practical problems.^{4,7}

Tests⁴ conducted in the ASHAE Environment Laboratory indicated that the *natural* convection from floors and ceilings can be calculated from Equations 4 to 9 which follow.

Natural convection from heated ceiling

$$q_c = 0.041 \frac{(t_p - t_a)^{1.25}}{D_p^{1.25}} \quad (4)$$

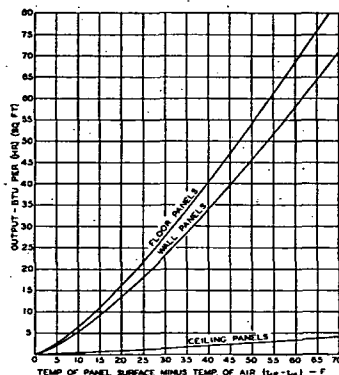


Fig. 10 Heat Output by Convection from Floor and Ceiling Panels

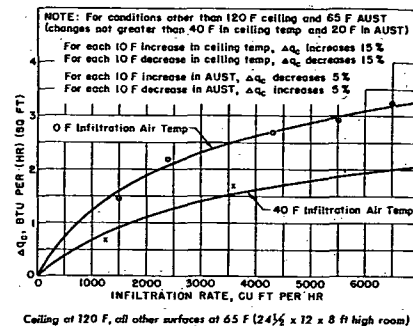


Fig. 11 Additional Heat Flow from Ceiling due to Infiltration Air⁴

Natural convection from heated floor

$$q_c = 0.39 \frac{(t_p - t_a)^{1.25}}{D_p^{1.25}} \quad (5)$$

Natural convection from heated wall

$$q_c = 0.29 \frac{(t_p - t_a)^{1.25}}{H^{1.25}} \quad (6)$$

where

q_c = heat transfer by convection, Btu per (hour) (square foot).

t_p = temperature of panel surface, Fahrenheit.

t_a = temperature of the air, Fahrenheit.

D_p = equivalent diameter of panel (area $\times 4 \div$ perimeter), feet.

H = height of wall panel, feet.

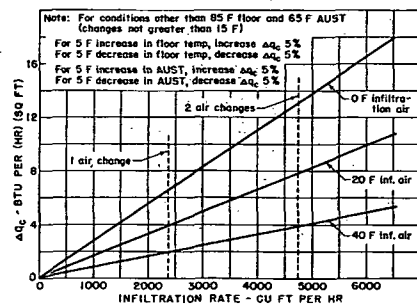


Fig. 12 Additional Heat Output from Floor due to Infiltration Air

Panel Heating

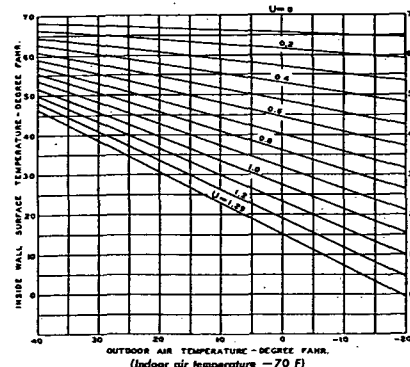


Fig. 13 Relation of Inside Surface Temperature to Overall Coefficient of Heat Transfer

Measurements of panel performance in furnished test rooms which did not have uniform temperature surfaces showed variations that are not large enough to be significant in heating practice.⁴ Other tests⁴ established that the effect of room size was also usually insignificant. The convection equations can therefore be simplified to:

Natural convection from heated ceiling

$$q_c = 0.021 (t_p - t_a)^{1.25} \quad (7)$$

Natural convection from heated floor

$$q_c = 0.32 (t_p - t_a)^{1.25} \quad (8)$$

Natural convection from heated wall

$$q_c = 0.26 (t_p - t_a)^{1.25} \quad (9)$$

Fig. 10 shows panel convection outputs calculated from these equations.

Infiltration and ventilation increase the convection from panels. Figs. 11 and 12 show the amount of increase Δq_c observed in the ASHAE Environment Laboratory.^{4,7} Equations 7 and 8 and Figs. 11 and 12 were used in the development of the design data for this chapter.

Combined Heat Transfer

The heat transfer from a panel to a room can be determined by adding the radiant heat transfer from Fig. 9 to the convective heat transfer from Fig. 10.

Use of Fig. 9 requires the calculation of the AUST, the area-weighted average surface temperature of the unheated surfaces in the room. In calculating AUST, the surface temperature of inside walls is assumed to be the same as the room air temperature. The surface temperatures of outside walls and exposed floors or ceilings can be obtained from Fig. 13 for a 70 F room air temperature. Corrections for other temperatures may be obtained from Fig. 14.

The combined heat transfer for ceiling panels and floor panels in rooms in which the air temperature is 70 to 76 F can be read directly from Figs. 15 and 16, respectively. These two diagrams apply to rooms in which the AUST

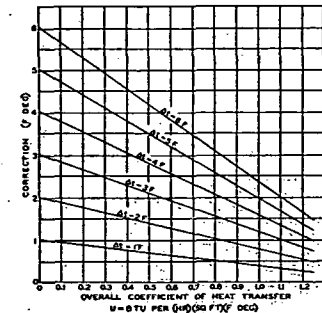


Fig. 14 Inside Wall Surface Temperature Correction for Air Temperatures Other Than 70 F

does not differ greatly from room air temperatures. Tests^{4,7} showed that the two temperatures are normally nearly equal.

Effect of Floor Coverings

Floor coverings may have a pronounced effect upon the performance of a floor panel system. The added thermal resistance of the floor covering causes a reduction in upward heat flow, and increases the heat flow to the underside of the

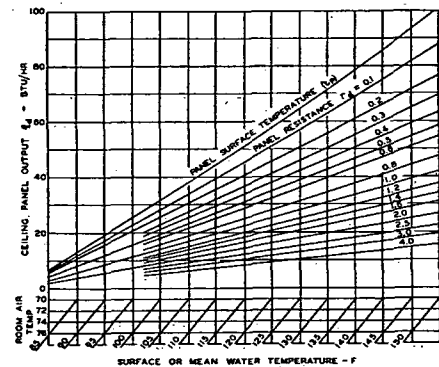


Fig. 15 Ceiling Panel Design Graph Showing Panel Surface Temperature and Mean Water Temperature vs Output Downward