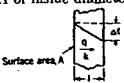
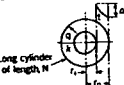
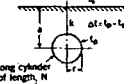
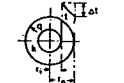
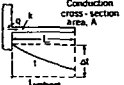
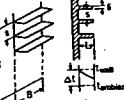


Table 6 . . . Solutions for Some Steady-State Thermal Conduction Problems^{a, b}

No.	System	Expressions for the Resistance R Entering into the Equation: $q = \Delta t/R$ (Btu per hour)
1.	Flat wall or curved wall if curvature is small (wall thickness less than 0.1 of inside diameter). 	$R = \frac{L}{kA}$
2.	Radial flow through a right circular cylinder. 	$R = \frac{\log_e \frac{r_2}{r_1}}{2\pi kN}$ (See footnote c).
3.	The buried cylinder. 	$R = \frac{\log_e \left(\frac{a + \sqrt{a^2 + r^2}}{r} \right)}{2\pi kN} = \frac{\cosh^{-1} \left(\frac{a}{r} \sqrt{1 + \frac{r^2}{a^2}} \right)}{2\pi kN}$ For $\frac{a}{r} \geq 3$, satisfactory approximation is: $R = \frac{\log_e \frac{2a}{r}}{2\pi kN} = \frac{\cosh^{-1} \frac{a}{r}}{2\pi kN}$
4.	Radial flow in a hollow sphere. 	$R = \frac{1}{4\pi k} \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$
5.	The straight fin or rod heated at one end. 	$R = \frac{m}{h_p \tanh mL}$ (see footnotes d and e). For $mL > 2.3$, $\tanh mL \approx 1$ $m = \sqrt{h_p p / kA}$ A = conduction cross-section area. p = perimeter of cross-section A . h_p = unit conductance to the surroundings from the fin surface. k = thermal conductivity fin material. Δt = wall temperature—ambient temperature.
6.	Finned surface of area HB . 	$R = \frac{(s + s)}{h_s \left(\frac{2}{m} \tanh mL + s \right) HB}$ $m = \sqrt{\frac{h_s p}{kA}} = \sqrt{\frac{2h_s}{k\delta}}$ Δt defined as in Case 5 above.

^a The dimensions to be employed in these solutions are: length of dimension p, L, r = feet; units of k = Btu per (hour) (square foot) (Fahrenheit degree for one foot thickness); units of h, Btu per (hour) (square foot) (Fahrenheit degree); units of area, A = square foot.

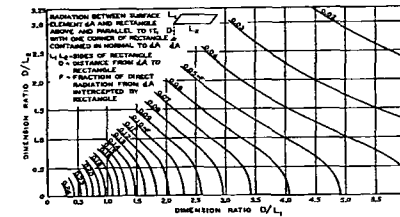
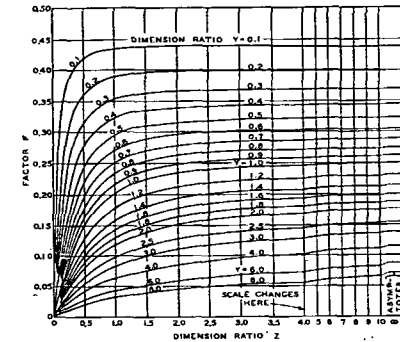
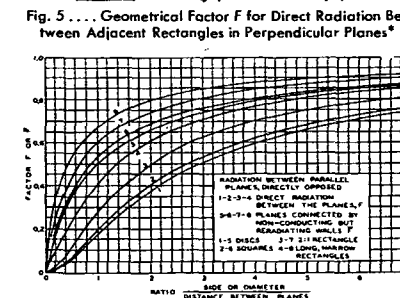
^b The thermal conductivity, k , in these solutions should be taken at the average material temperature.

^c $\log_e x = 2.303 \log_{10} x$.

^d This expression can also be employed as an approximation for tapered fin or of annular fin by employing average magnitudes of A and p .

^e $\tanh$ is the hyperbolic tangent.

Heat Transfer

Fig. 4 . . . Geometrical Factor F for Direct Radiation Between an Element dA and a Parallel Rectangle*Fig. 5 . . . Geometrical Factor F for Direct Radiation Between Adjacent Rectangles in Perpendicular Planes*Fig. 6 . . . Geometrical Factor F for Direct Radiation Between Opposed Parallel Rectangle and Discs of Equal Size*

* H. C. Hotell, Radiant heat transmission, (Mechanical Engineering, July 1930, pp. 700 to 702).

convection between the water and the pipe wall. The equation for this case is the following:

$$h_c = 13.9(t_f)^{0.445} \frac{u_m^{0.8}}{D^{0.3}} \quad (17)$$

where

$$u_m = 5 \text{ fps}$$

$$D = \frac{2.067}{12} = 0.1725 \text{ ft}$$

$$t_f = \frac{34 + 36}{2} = 35 \text{ F}$$

$$h_c = \frac{13.9 \times 6.9 \times 3.62}{0.703} = 494 \text{ Btu per (hr) (sq ft) (F deg.)}$$

This heat transfer rate is through the inner surface of the pipe and it is, therefore, this area that determines the resistance R_1 .

$$A = \pi D = 0.542 \text{ sq ft per unit length of pipe,}$$

and therefore

$$R_1 = \frac{1}{h_c A} = \frac{1}{494 \times 0.542}$$

$$R_1 = 3.73 \times 10^{-3} \text{ (hr) (F deg) per Btu.}$$

Case 11 of Table 2 fits the conditions of the problem if only free convection heating of the pipe is assumed. The equation in this case is as follows:

$$h_c = 0.271 \left(\frac{P}{P_s} \right)^{0.4} \left(\frac{\Delta t}{D} \right)^{0.25} \quad (18)$$

where

$$\Delta t = 20 \text{ F}$$

$$D = 0.364 \text{ ft}$$

$$P = P_s = \text{one atmosphere}$$

therefore,

$$h_c = 0.271 \left(\frac{20}{0.364} \right)^{0.25}$$

$$h_c = 0.737 \text{ Btu per (hr) (sq ft) (F deg.)}$$

Using the surface area of the insulation, the value of the resistance per unit length is determined.

$$A = \pi \left(\frac{4.375}{12} \right) \times 1 = 1.14 \text{ sq ft}$$

$$R_s = \frac{1}{h_c A} = \frac{1}{0.737 \times 1.14}$$

$$R_s = 1.19 \text{ (hr) (F deg) per Btu.}$$

This result may not be deemed conservative inasmuch as the expression is for still air. If, however, the air is not still, but flows at approximately 5 mph or 7 fps, the heat transfer equation for forced convection would apply. This equation is Case 5 of Table 2.

$$h_{c(\text{airflow})} = 0.211(T_f)^{0.445} \frac{(u_m)^{0.8}}{D^{0.3}} \quad (19)$$