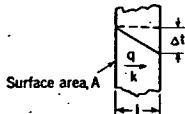
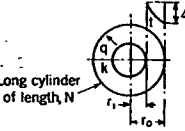
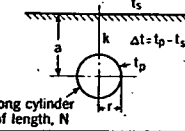
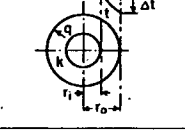
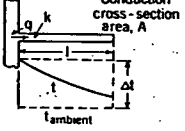
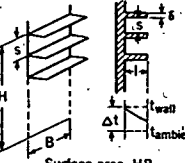


TABLE 8. SOLUTIONS FOR SOME STEADY-STATE THERMAL CONDUCTION PROBLEMS^{a,b}

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. 	$R = \frac{\log_e \frac{r_o}{r_i}}{2\pi kN}$ (See footnote c).
3.	The buried cylinder. 	$R = \frac{\log_e \frac{2a}{r}}{2\pi kN}$; $R = \frac{\cosh^{-1} \frac{a}{r}}{2\pi kN}$ for $\frac{a}{r} \geq 3$ (See footnote c).
4.	Radial flow in a hollow sphere. 	$R = \frac{\frac{1}{r_i} - \frac{1}{r_o}}{4\pi k}$
5.	The straight fin or rod heated at one end. 	$R = \frac{m}{h_p \tanh ml}$ (see footnotes d and e). For $ml > 2.3$, $\tanh ml \approx 1$ $m = \sqrt{h_p/kA}$ 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 temp.
6.	Finned surface of area HB . 	$R = \frac{(s + \delta)}{h_p \left(\frac{2}{m} \tanh ml + s \right) HB}$ $m = \sqrt{\frac{h_p p}{kA}} = \sqrt{\frac{2 h_p}{k\delta}}$ Δt defined as in Case 5 above.

^aThe dimensions to be employed in these solutions are: length of dimension p, l, r = feet; units of k = Btu per hour per square foot per degree Fahrenheit for one foot thickness; units of h , Btu per hour per square foot per degree Fahrenheit; units of area, A = square feet.
^bThe thermal conductivity, k , in these solutions should be taken at the average material temperature (see Table 5).

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

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

^eTanh is the hyperbolic tangent.

where the resultant parallel resistance R_4 is obtained from:

$$\frac{1}{R_4} = \frac{1}{R_r} + \frac{1}{R_c}$$

Provided the individual resistances may be evaluated, the total resistance can be obtained from this relation. Then the heat transfer current for the length of pipe (N , ft) can be established by the relation:

$$q_{rc} \text{ (Btu per hour)} = \frac{t_o - t_f}{R_T} \quad (10)$$

For a unit length of the pipe the heat transfer rate is:

$$\frac{q_{rc}}{N} \text{ (Btu per hour foot)} = \frac{(t_o - t_f)}{R_T N} \quad (11)$$

The temperature drop, Δt , through an individual resistance may then be calculated from the relation:

$$\Delta t = R q_{rc}$$

where R is the resistance in question.

The problem is now reduced to one of evaluating the individual resistances of the system. This entails suitable integration of the rate Equations 1, 2 and 3 to produce expressions of the form:

$$q = \frac{\Delta t}{R} \quad (12)$$

where q is the heat transfer rate, and Δt is the potential drop or temperature difference through the resistance R . Table 8 lists such solutions for six different conduction systems. Table 2 in Chapter 4 and Table 1 of this chapter indicate the magnitudes of the thermal conductivities, k , to be employed in the expressions of Table 8.

The solution applicable to the problem depicted in Fig. 4, for the calculation of R_2 and R_3 , is case 2 in Table 8. Thus for a 1 ft length of 2 in. nominal size pipe (I. D. = 2.067 in., O. D. = 2.375 in.) insulated with 1 in. of cork:

$$R_2 = \frac{\log_e \frac{1.188}{1.033}}{2\pi \times 26 \times 1} = 8.5 \times 10^{-4} \text{ hr degree Fahrenheit per Btu.}$$

$$R_3 = \frac{\log_e \frac{2.188}{1.188}}{2\pi \times 0.025 \times 1} = 3.9 \text{ hr degree Fahrenheit per Btu.}$$

The convection resistances to heat transfer from the pipe wall to the cold water, R_1 , and from the air to the surface of the insulating material, R_c , are dependent on the flow conditions prevailing at these surfaces, and on the thermal properties of the fluids. The unit conductances for thermal convection, h , Btu per hour per square foot per degree Fahrenheit, have been determined by test for many flow systems. These data may be employed to predict the conductances for *similar flow systems*. Table 5 summarizes some empirical equations expressing such test results.