THIRD EDITION

Introduction to Heat Transfer

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capacity rates are equal ($C_h = C_c$). The temperature difference ΔT must then be a constant throughout the exchanger, in which case $\Delta T_1 = \Delta T_2 = \Delta T_{lm}$.

11.3.4 Multipass and Cross-Flow Heat Exchangers

Although flow conditions are more complicated in multipass and cross-flow heat exchangers, Equations 11.6, 11.7, 11.14, and 11.15 may still be used if the following modification is made to the log mean temperature difference [6]:

$$\Delta T_{lm} = F\,\Delta T_{lm,\,CF} \tag{11.18}$$

That is, the appropriate form of ΔT_{lm} is obtained by applying a correction factor to the value of ΔT_{lm} that would be computed *under the assumption of counter-flow conditions.* Hence from Equation 11.17, $\Delta T_1 = T_{h,i} - T_{c,o}$ and $\Delta T_2 = T_{h,o} - T_{c,i}$.

Algebraic expressions for the correction factor F have been developed for various shell-and-tube and cross-flow heat exchanger configurations [1, 6, 7], and the results may be represented graphically. Selected results are shown in Figures 11.10 to 11.13 for common heat exchanger configurations. The notation (T, t) is used to specify the fluid temperatures, with the variable t always assigned to the tube-side fluid. With this convention it does not matter whether the hot fluid or the cold fluid flows through the shell or the tubes. An important implication of Figures 11.10 to 11.13 is that, *if the temperature change of one fluid is negligible,* either P or R is zero and F is 1. *Hence heat exchanger behavior is independent of the specific configuration.* Such would be the case if one of the fluids underwent a phase change.

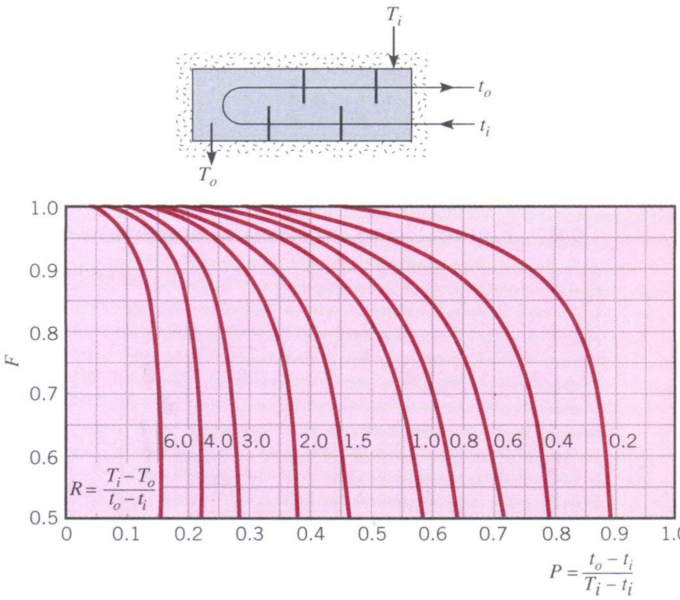

FIGURE 11.10 Correction factor for a shell-and-tube heat exchanger with one shell and any multiple of two tube passes (two, four, etc. tube passes).

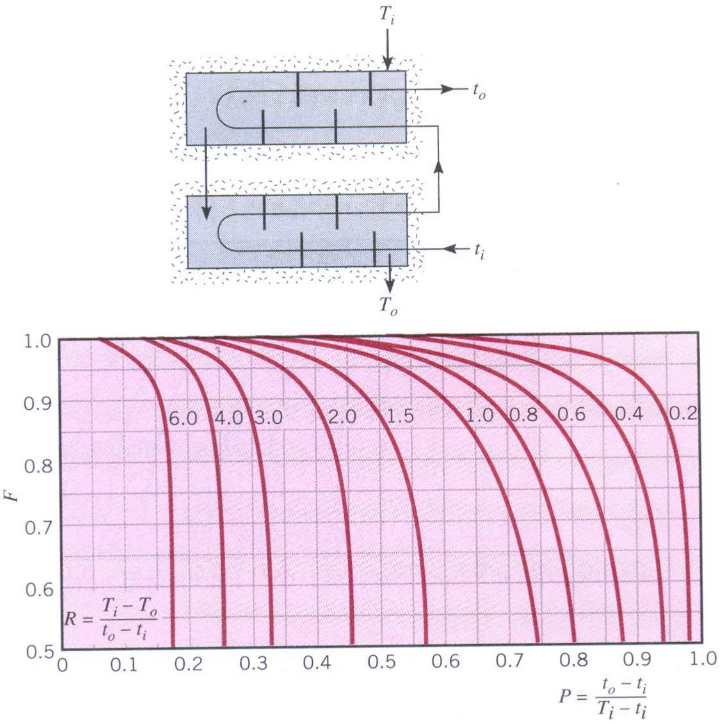

FIGURE 11.11 Correction factor for a shell-and-tube heat exchanger with two shell passes and any multiple of four tube passes (four, eight, etc. tube passes).

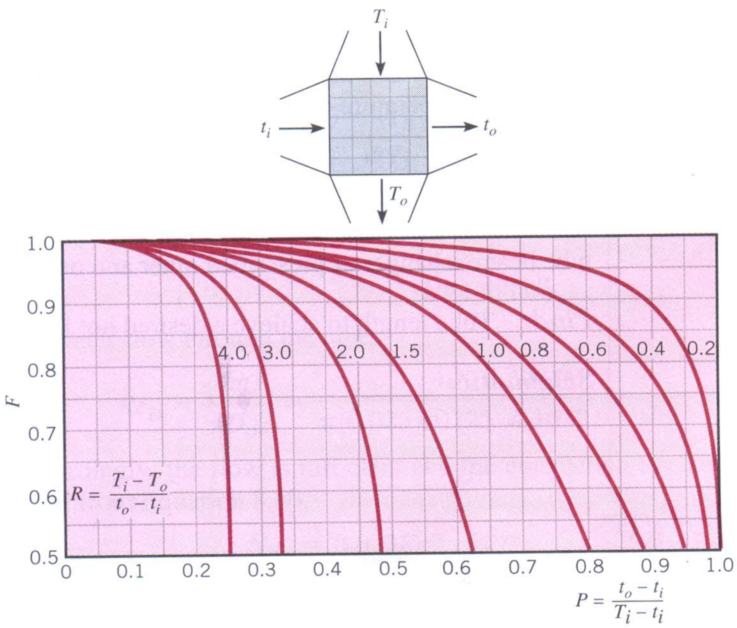

FIGURE 11.12 Correction factor for a single-pass, cross-flow heat exchanger with both fluids unmixed

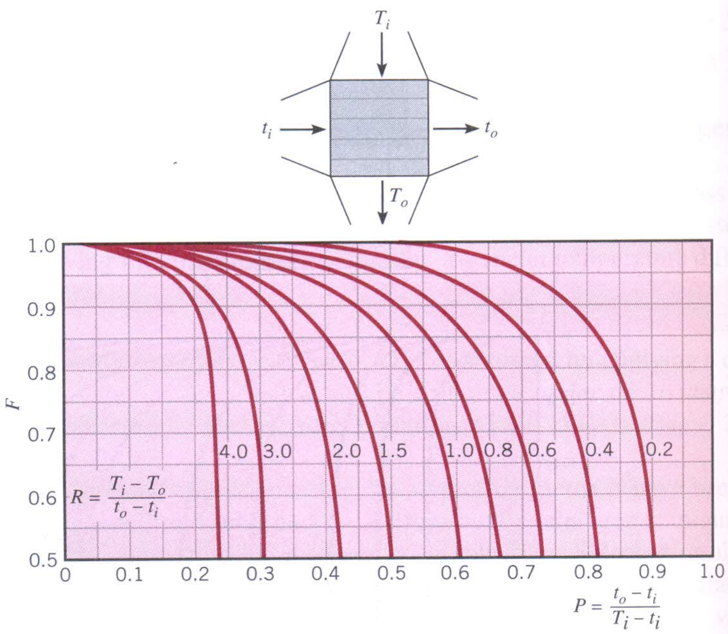

FIGURE 11.13 Correction factor for a single-pass, cross-flow heat exchanger with one fluid mixed and the other unmixed.

EXAMPLE 11.1

A counterflow, concentric tube heat exchanger is used to cool the lubricating oil for a large industrial gas turbine engine. The flow rate of cooling water through the inner tube (D_i = 25 mm) is 0.2 kg/s, while the flow rate of oil through the outer annulus (D_o = 45 mm) is 0.1 kg/s. The oil and water enter at temperatures of 100 and 30°C, respectively. How long must the tube be made if the outlet temperature of the oil is to be 60°C?

SOLUTION

Known: Fluid flow rates and inlet temperatures for a counterflow, concentric tube heat exchanger of prescribed inner and outer diameter.

Find: Tube length to achieve a desired hot fluid outlet temperature.

Schematic: