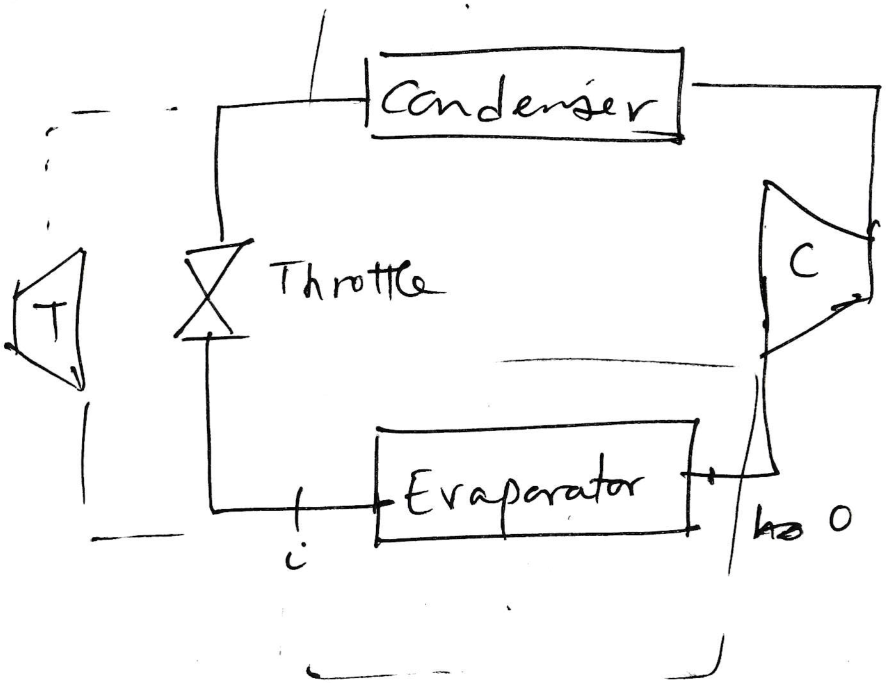


- Reciprocating compressor

Heat Exchangers

$$Q = (H_o - H_i)$$

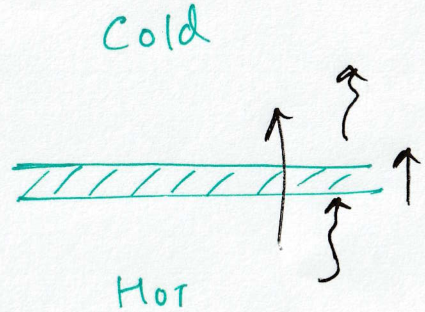
$$\dot{Q} = UA(\Delta T)$$

Temperature Difference

Area

overall heat transfer coefficent

FIGURE 11.1 Concentric tube heat exchangers. (a) Parallel flow. (b) Counterflow.



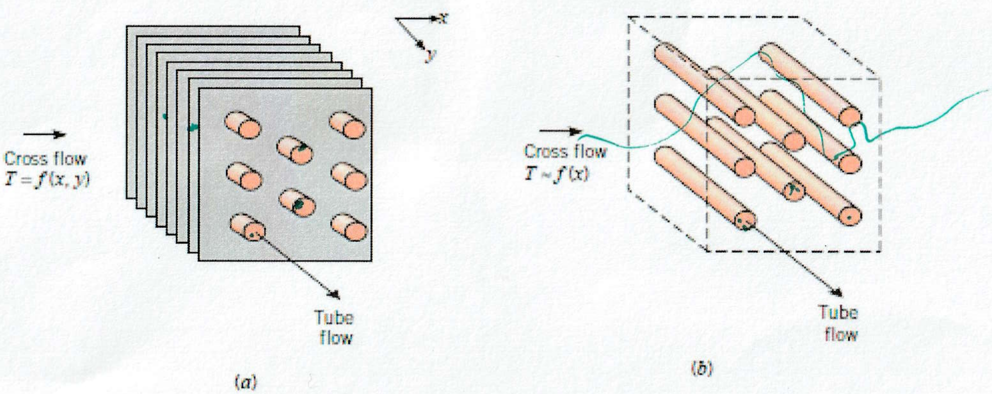


FIGURE 11.2 Cross-flow heat exchangers. (a) Finned with both fluids unmixed. (b) Unfinned with one fluid mixed and the other unmixed.

3

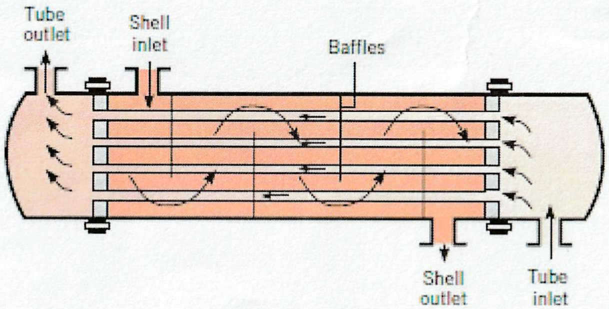
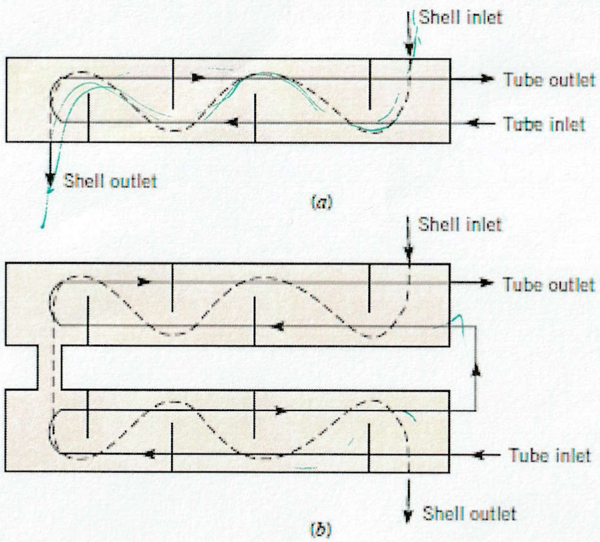


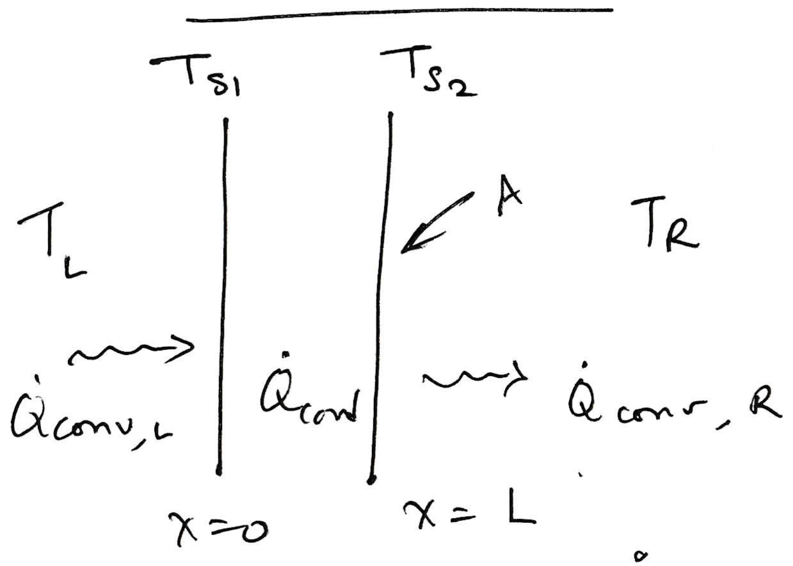
FIGURE 11.3 Shell-and-tube heat exchanger with one shell pass and one tube pass (cross-counterflow mode of operation).



1 shell pass
2 tube passes

FIGURE 11.4 Shell-and-tube heat exchangers. (*a*) One shell pass and two tube passes. (*b*) Two shell passes and four tube passes.

4



$$\dot{Q}_{cond} = \frac{kA(T_{s_1} - T_{s_2})}{L}$$

$$\dot{Q}_{conv,L} = h_L A (T_L - T_{s_1})$$

$$\dot{Q}_{conv,R} = h_R A (T_{s_2} - T_R)$$

$$\dot{Q}_{conv,L} = \dot{Q}_{cond} = \dot{Q}_{conv,R} = \dot{Q}$$

(steady state)

$$T_L - T_{s_1} = \frac{\dot{Q}}{h_L A}$$

$$+\ T_{s_1} - T_{s_2} = \frac{\dot{Q}}{KA/L}$$

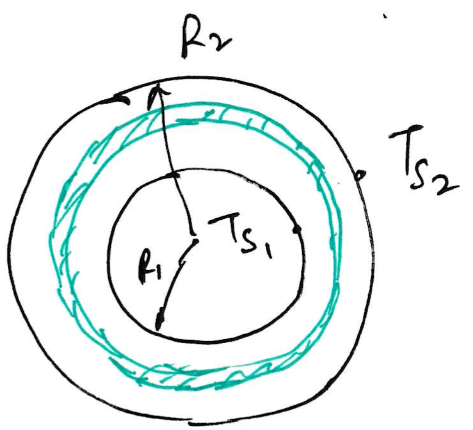
$$+\ T_{s2} - T_R = \frac{\dot{Q}}{h_R A}$$

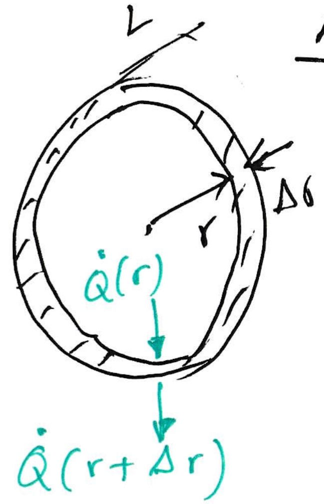
$$T_L - T_R = \dot{Q}\left[\frac{1}{h_L A} + \frac{1}{KA/L} + \frac{1}{h_R A}\right]$$

$$\Rightarrow \quad \dot{Q} = \frac{1}{\cancel{1/h_L} + \cancel{k/kA} +}$$

$$\dot{Q} = \underbrace{\frac{1}{\left(\frac{1}{h_L} + \frac{L}{k} + \frac{1}{h_R}\right)}}_{U} A\,(T_L - T_R)$$

$$U = \frac{1}{\frac{1}{h_L} + \frac{L}{k} + \frac{1}{h_R}}$$





Energy Balance $\quad \dot{Q}(r) - \dot{Q}(r+\Delta r) = 0$

$$\dot{Q}(r) = \dot{Q}(r+\Delta r)$$

$$\Rightarrow \cancel{\dot{Q}(r)} = \cancel{\dot{Q}(r)} + \frac{d\dot{Q}}{dr}\Delta r$$

$$\frac{d\dot{Q}}{dr} = 0$$

$$\dot{Q} = -kA\frac{dT}{dr}$$

$$= -k\,2\pi r L\frac{dT}{dr}$$

Since $\frac{d\dot{Q}}{dr} = 0 \Rightarrow \dot{Q} = C_1$

$$\Rightarrow +k\,2\pi r L\frac{dT}{dr} = C_1$$

$$\Rightarrow \frac{dT}{dr} = \frac{C_1}{r}\left(\frac{1}{2\pi L}\right)\frac{1}{k} \Rightarrow T(r) = \frac{C_1}{(2\pi L k)}\ln r + C_2$$

BC. $T(R_1) = T_{s_1}$ $\quad T(R_2) = T_{s_2}$

(6)

$$T(R_2) = \frac{\ln R_2}{2\pi L K} C_1 + C_2 = T_{s_2}$$

$$T(R_1) = \frac{\ln R_1}{2\pi L k} C_1 + C_2 = T_{s_1}$$

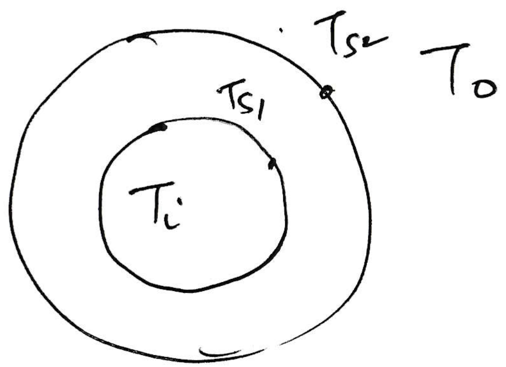
$$\begin{bmatrix} \frac{\ln R_2}{2\pi L K} & 1 \\ \frac{\ln R_1}{2\pi L K} & 1 \end{bmatrix} \begin{bmatrix} C_1 \\ C_2 \end{bmatrix} = \begin{bmatrix} T_{s_2} \\ T_{s_1} \end{bmatrix}$$

$$C_1 = \frac{\begin{vmatrix} T_{s_2} & 1 \\ T_{s_1} & 1 \end{vmatrix}}{\frac{\ln R_2/R_1}{2\pi L K}} \quad ; \quad C_2 = \frac{\begin{vmatrix} \frac{\ln R_2}{2\pi L K} & T_{s_2} \\ \frac{\ln R_1}{2\pi L K} & T_{s_1} \end{vmatrix}}{\frac{\ln R_2/R_1}{2\pi L K}}$$

$$= \frac{T_{s_2} - T_{s_1}}{\frac{\ln R_2/R_1}{2\pi L K}} \qquad = \frac{\frac{T_{s_1} \ln R_2 - T_{s_2} \ln R_1}{2\pi L K}}{\frac{\ln R_2/R_1}{2\pi L K}}.$$

$$\dot{Q} = \frac{(T_{s_2} - T_{s_1})}{(\ln R_2/R_1)/2\pi L k}$$

(7)



$$\left.\begin{aligned}
\dot{Q}_i &= h_i A_i (T_i - T_{s_1}) \quad \text{(conv)} \\
\dot{Q}_{cond} &= \frac{(T_{s_1} - T_{s2})}{\dfrac{\ln R_2/R_1}{2\pi L K}} \\
\dot{Q}_o &= h_o A_o (T_{s_2} - T_o)
\end{aligned}\right\} \Rightarrow
\begin{aligned}
T_i - T_{s_1} &= \frac{\dot{Q}}{h_i A_i} \\
T_{s_1} - T_2 &= \frac{\dot{Q}}{\dfrac{2\pi L K}{\ln R_2/R_1}} \\
T_{s_2} - T_o &= \frac{\dot{Q}}{h_o A_o}.
\end{aligned}$$

$$T_i - T_o = \dot{Q} \underbrace{\left[\frac{1}{h_i A_i} + \frac{\ln R_2/R_1}{2\pi L K} + \frac{1}{h_o A_o} \right]}_{= 1/U} = \frac{1}{U}$$

$$\dot{Q} = U (T_i - T_o)$$