Heat Exchangers

A heat exchanger is any device that affects the transfer of thermal energy from one fluid to another.

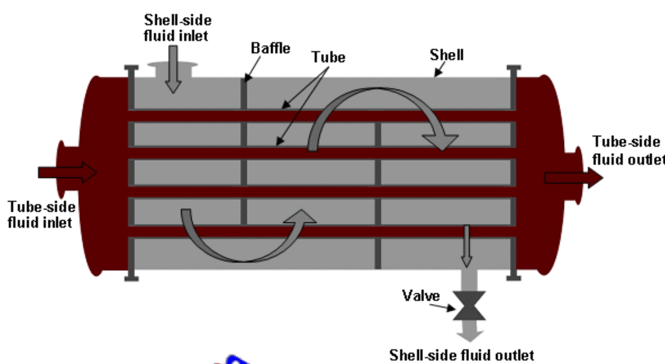
Types of Heat Exchangers

Heat exchangers are typically classified according to flow arrangement and types of construction.

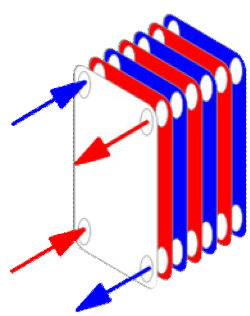
According to flow arrangement:

1) Co-Current flow H.E, 2) Counter-Current flow H.E, 3) Cross flow H.E.
Common H.E according to types of construction:

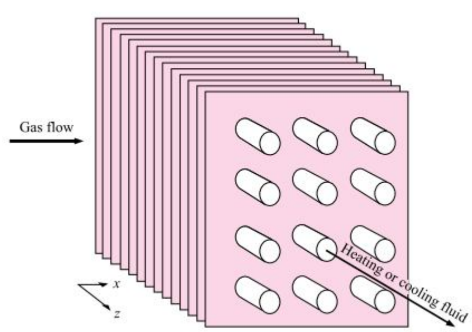
1) Shell and tube heat exchange



2) Plate heat exchanger



3) Cross flow heat exchanger



The study of the H.E aimed to calculate the required surface area for the heat transfer process.

Heat Transfer Calculation

$$q = UA\,\Delta T_{\text{overall}}$$

U is the overall heat-transfer coefficient.

For plane wall:

$$U = \frac{1}{1/h_o + \Delta x/k + 1/h_i}$$

For cylindrical wall:

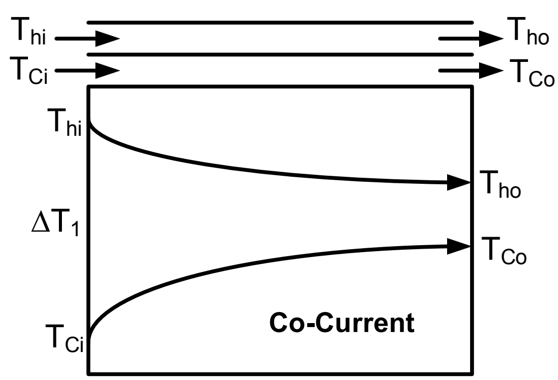
$$U_i = \frac{1}{\dfrac{1}{h_i} + \dfrac{A_i \ln(r_o/r_i)}{2\pi k L} + \dfrac{A_i}{A_o}\dfrac{1}{h_o}} \quad ; \qquad q = U_i\, A_i\, \Delta T_{overall}$$

$$U_o = \frac{1}{\dfrac{A_o}{A_i}\dfrac{1}{h_i} + \dfrac{A_o \ln(r_o/r_i)}{2\pi k L} + \dfrac{1}{h_o}} \quad ; \qquad q = U_0\, A_0\, \Delta T_{overall}$$

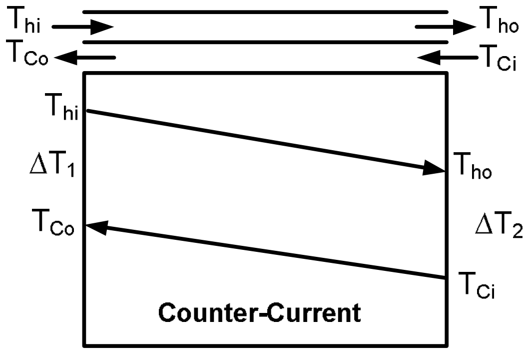
$$\Rightarrow U_i\, A_i = U_0 A_0 \Rightarrow D_i U_i = D_0 U_0$$

Log Mean Temperature Difference (LMTD)

For H.E shown,



$$\Delta T_1 = T_{hi} - T_{Ci}$$
$$\Delta T_2 = T_{ho} - T_{Co}$$



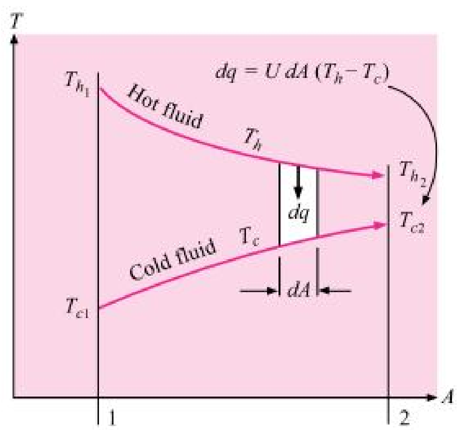
$$\Delta T_1 = T_{h\,i} - T_{Co}$$

$$\Delta T_2 = T_{h\,o} - T_{Ci}$$

The average temperature difference is called the Log-Mean Temperature Difference (LMTD), which can be defined as

$$\Delta T = \Delta T_{LM} = LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln \dfrac{\Delta T_1}{\Delta T_2}}$$

In order to prove that,



$$q = UA\,\Delta T_m \qquad \textbf{[10-5]}$$

The heat transferred through an element of area *dA* may be written

$$dq = -\dot{m}_h c_h dT_h = \dot{m}_c c_c dT_c \qquad \textbf{[10-6]}$$

where the subscripts h and c designate the hot and cold fluids, respectively. The heat transfer could also be expressed

$$dq = U(T_h - T_c)dA \qquad \textbf{[10-7]}$$

From Equation (10-6)

$$dT_h = \frac{-dq}{\dot{m}_h c_h}$$

$$dT_c = \frac{dq}{\dot{m}_c c_c}$$

where $\dot{m}$ represents the mass-flow rate and c is the specific heat of the fluid. Thus

$$dT_h - dT_c = d(T_h - T_c) = -dq\left(\frac{1}{\dot{m}_h c_h} + \frac{1}{\dot{m}_c c_c}\right) \qquad \textbf{[10-8]}$$

Solving for dq from Equation (10-7) and substituting into Equation (10-8) gives

$$\frac{d(T_h - T_c)}{T_h - T_c} = -U\left(\frac{1}{\dot{m}_h c_h} + \frac{1}{\dot{m}_c c_c}\right)dA \qquad \textbf{[10-9]}$$

This differential equation may now be integrated between conditions 1 and 2 as indicated in Figure 10-7. The result is

$$\ln\frac{T_{h2} - T_{c2}}{T_{h1} - T_{c1}} = -UA\left(\frac{1}{\dot{m}_h c_h} + \frac{1}{\dot{m}_c c_c}\right) \qquad \textbf{[10-10]}$$

Returning to Equation (10-6), the products $\dot{m}_c c_c$ and $\dot{m}_h c_h$ may be expressed in terms of the total heat transfer q and the overall temperature differences of the hot and cold fluids. Thus

$$\dot{m}_h c_h = \frac{q}{T_{h1} - T_{h2}}$$

$$\dot{m}_c c_c = \frac{q}{T_{c2} - T_{c1}}$$

Substituting these relations into Equation (10-10) gives

$$q = UA\frac{(T_{h2} - T_{c2}) - (T_{h1} - T_{c1})}{\ln[(T_{h2} - T_{c2})/(T_{h1} - T_{c1})]} \qquad \textbf{[10-11]}$$

Comparing Equation (10-11) with Equation (10-5), we find that the mean temperature difference is the grouping of terms in the brackets. Thus

$$\Delta T_m = \frac{(T_{h2} - T_{c2}) - (T_{h1} - T_{c1})}{\ln[(T_{h2} - T_{c2})/(T_{h1} - T_{c1})]} \qquad \textbf{[10-12]}$$

This temperature difference is called the log mean temperature difference (LMTD).