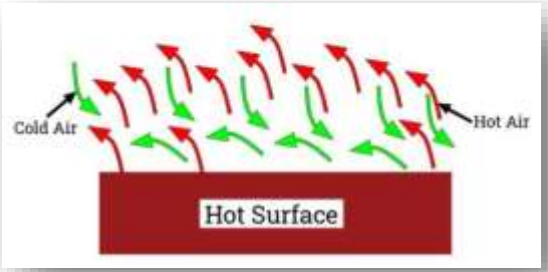
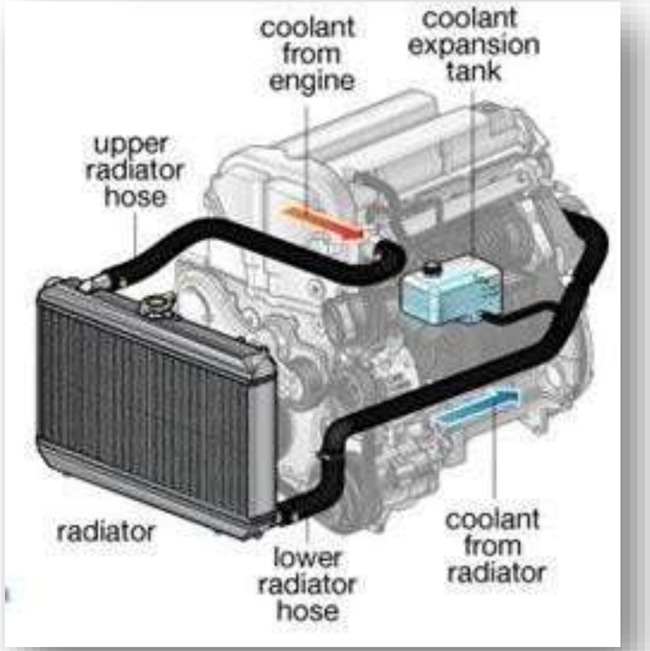
HEAT EXCHANGERS

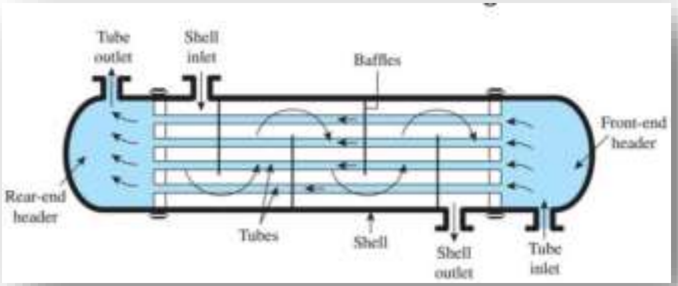
LMTD & NTU METHODS

HEAT EXCHANGERS

- System to Transfer Heat - Source & Fluid
- Either to Cool or Heat Source/Fluid
- Separated by Wall or Tubes or Baffles
- Classified on Nature & Amount Heat Transfer
- LMTD & NTU – Helps to Estimate Heat Transfer

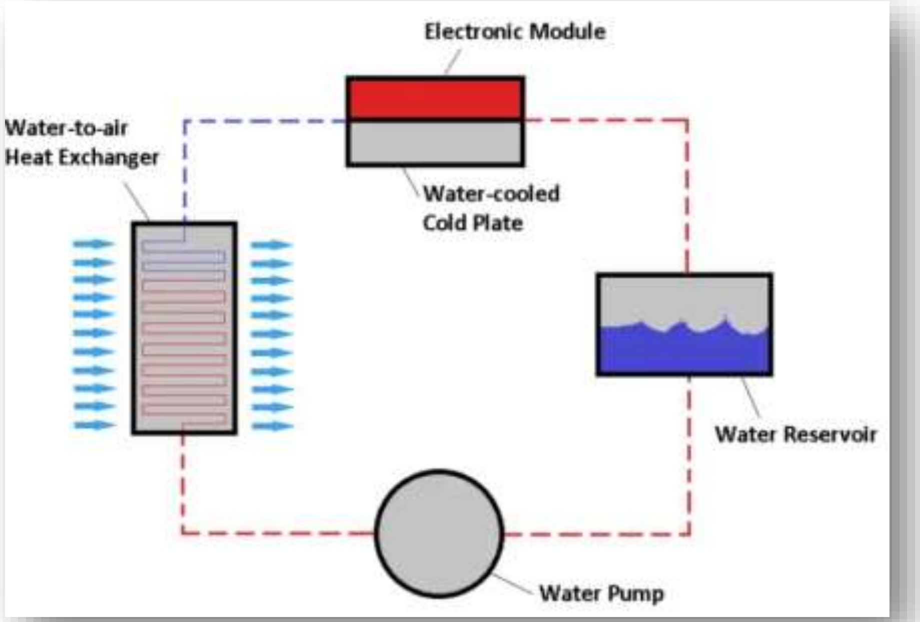


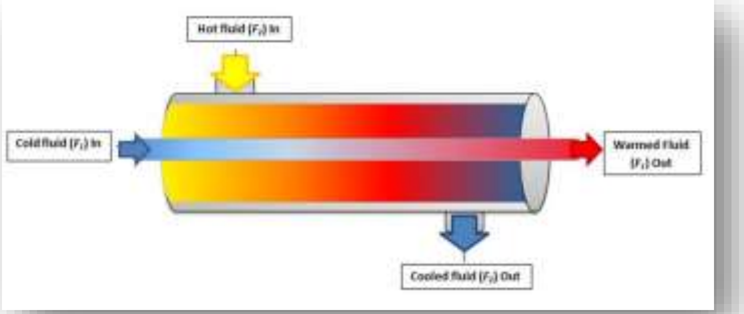




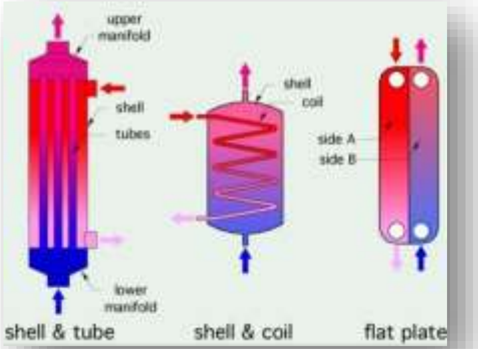
HEAT EXCHANGER - MECHANISM

- Fluid Flows around the Heat Source
- Extract the Heat form Heat Source
- Fluid Transfers the Heat outside
- Fluid & Flow Properties - Decider
- Water, Oil & Air are Commonly Used

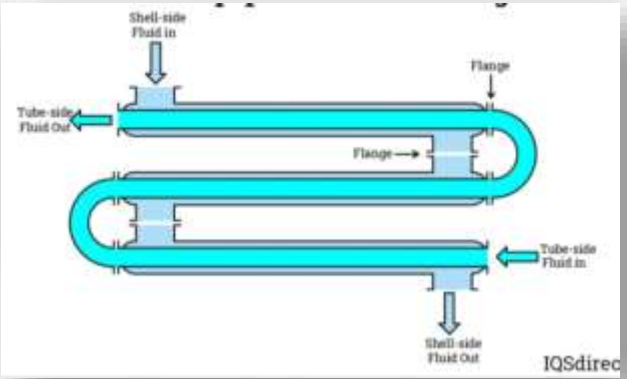


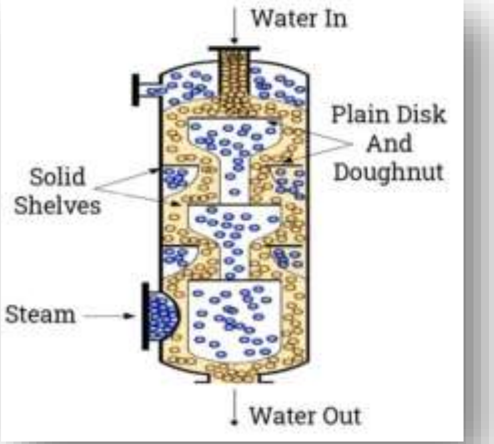


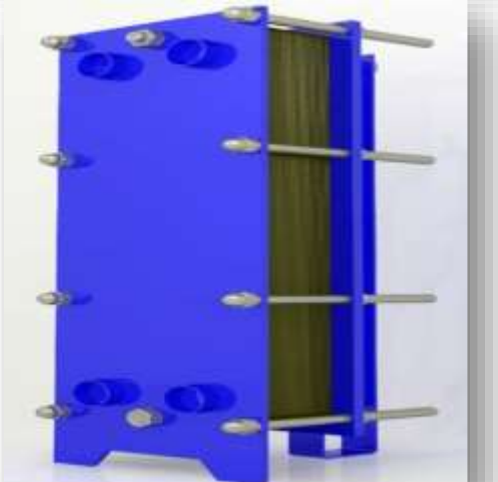
HEAT EXCHANGER - CLASSIFICATIONS



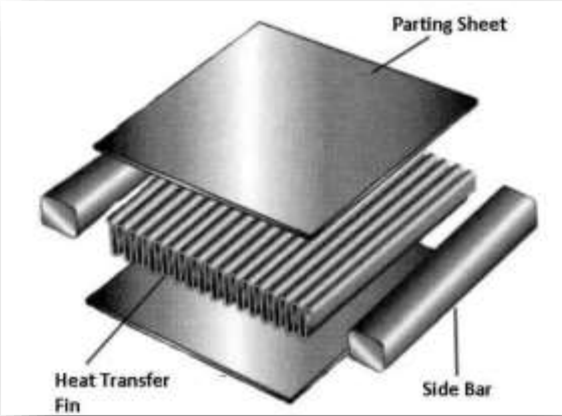
- Tube in Tube Heat Exchangers
- Double Pipe Heat Exchangers
- Direct Contact Heat Exchangers
- Plate & Frame Heat Exchangers



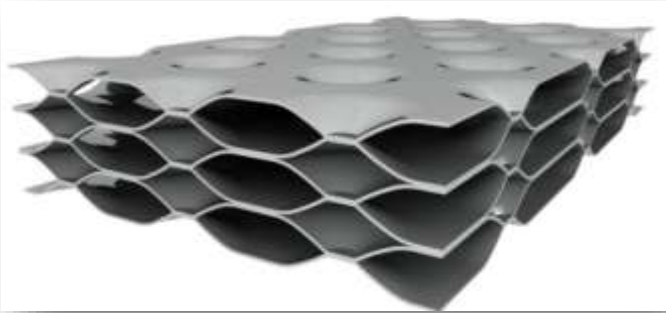


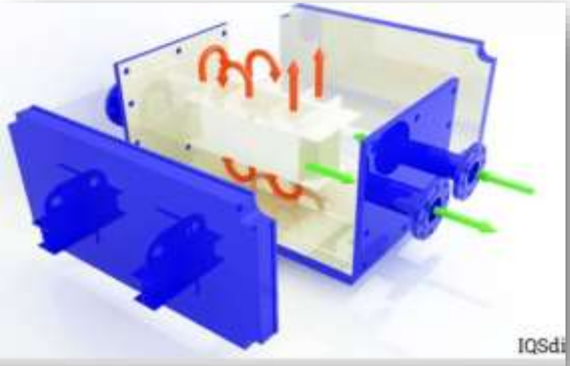


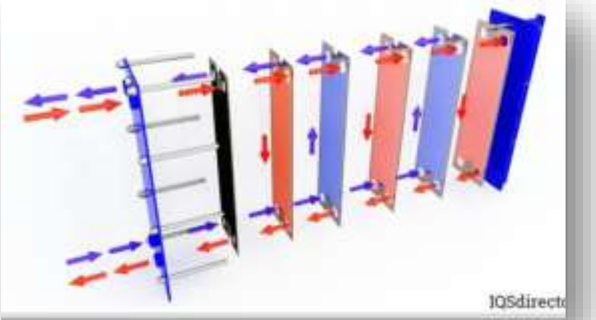
HEAT EXCHANGER - CLASSIFICATIONS



- Finned Tube Heat Exchangers
- Pillow Heat Exchangers
- Hybrid Heat Exchangers
- Gasketed Plate Heat Exchangers

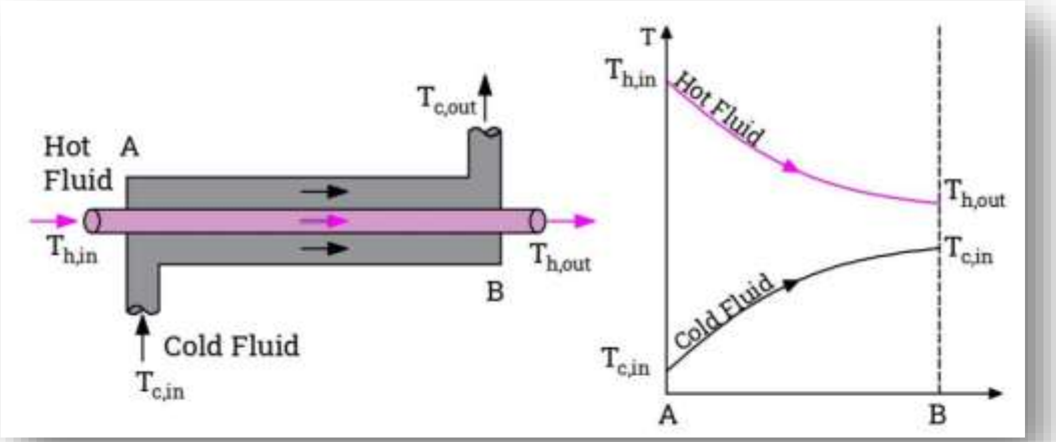


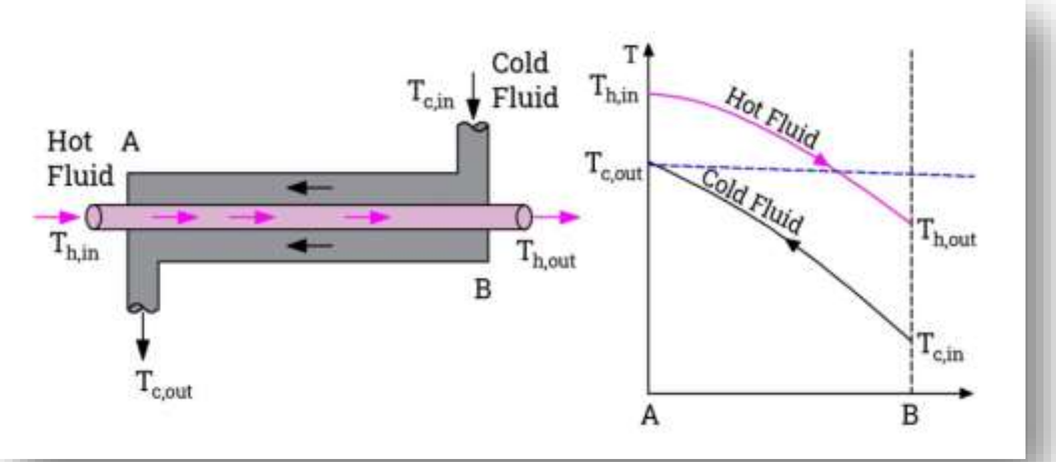




SHELL & TUBE HEAT EXCHANGER

- Parallel Flow Heat Exchanger
  - Co Current Flow
- Counter Flow Heat Exchanger
  - Counter Current Flow





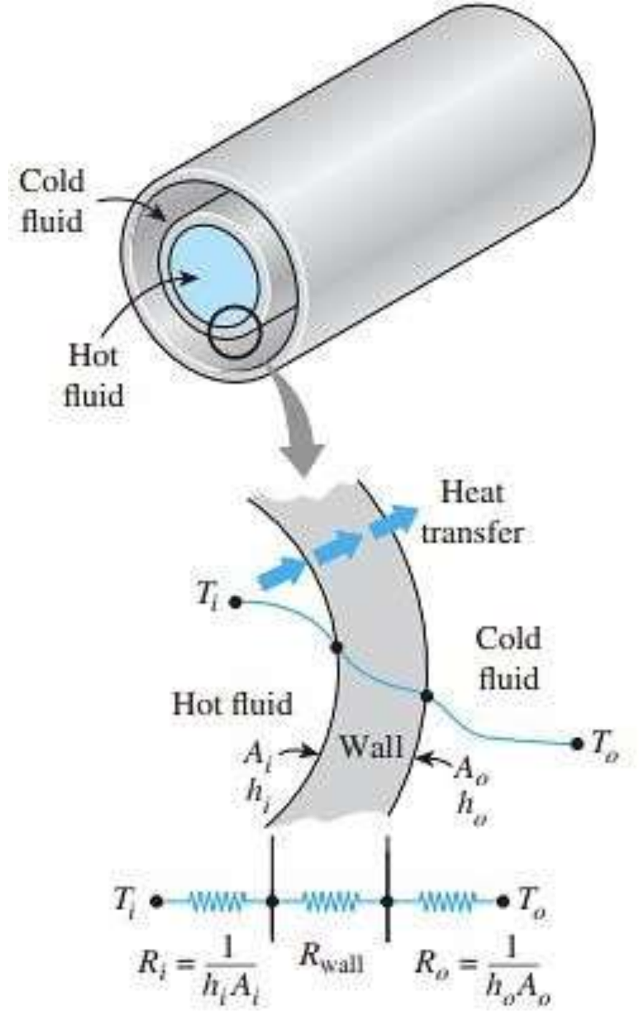
OVERALL HEAT TRANSFER COEFFICIENT

- Combined Heat Transfer Involved
  - Conduction, Convection & Radiation

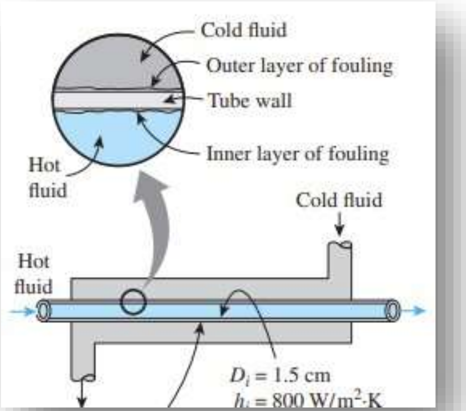
$$R = R_{\text{total}} = R_i + R_{\text{wall}} + R_o = \frac{1}{h_i A_i} + \frac{\ln(D_o/D_i)}{2\pi k L} + \frac{1}{h_o A_o}$$

- Thermal Resistance Helps Analysis
  - Equivalent Circuit Established

$$\frac{1}{UA_s} = \frac{1}{U_i A_i} = \frac{1}{U_o A_o} = R = \frac{1}{h_i A_i} + R_{\text{wall}} + \frac{1}{h_o A_o}$$

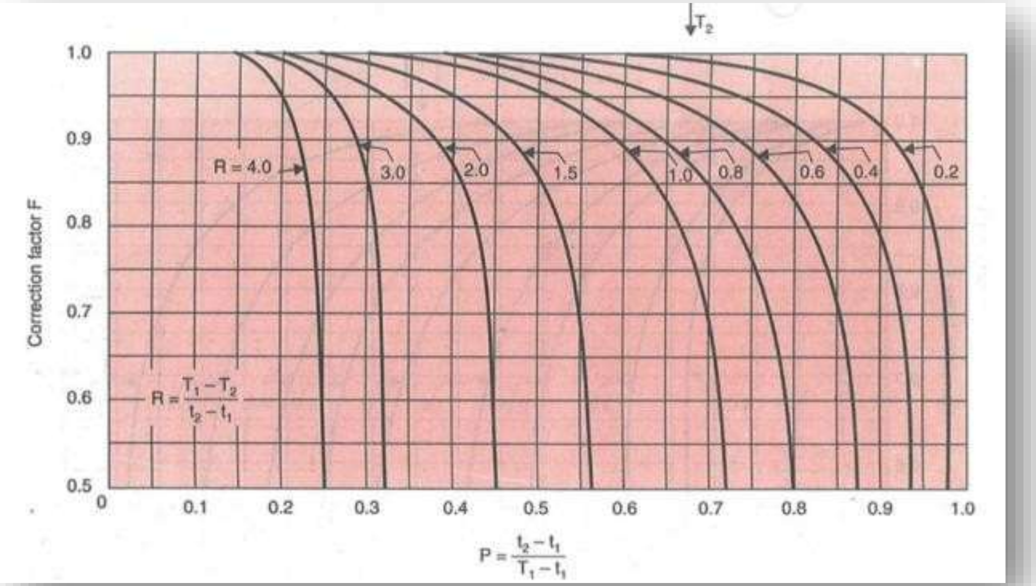


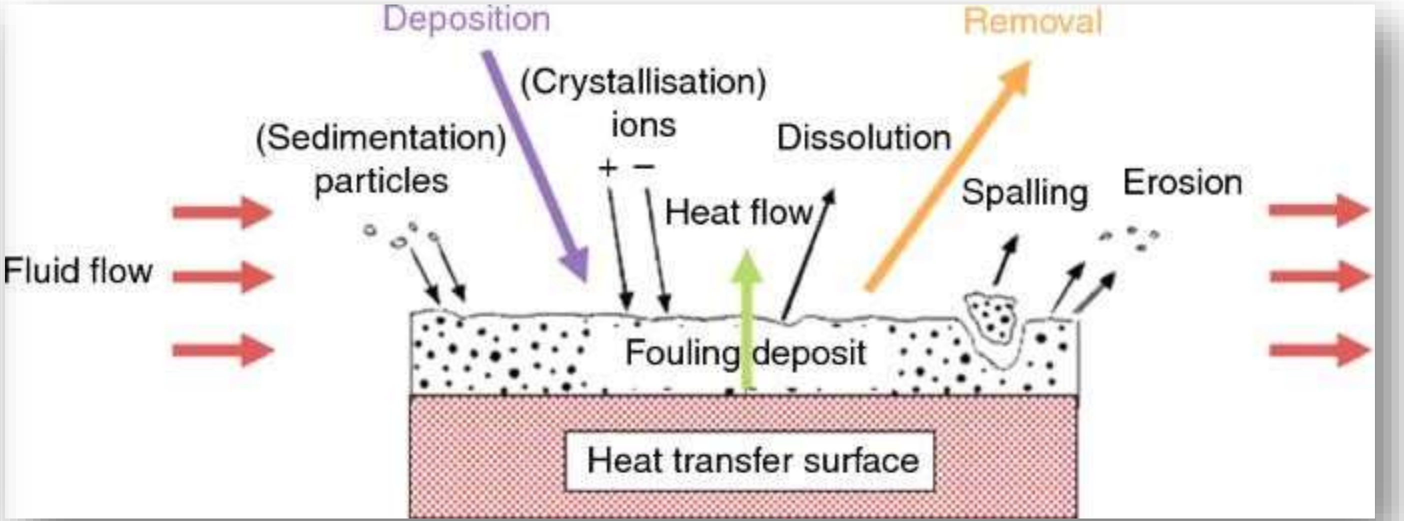
Fouling Factor



- Impurities Promote Fouling in Heat Exchanger Tube Wall

- Extensively Affect the Heat Transfer

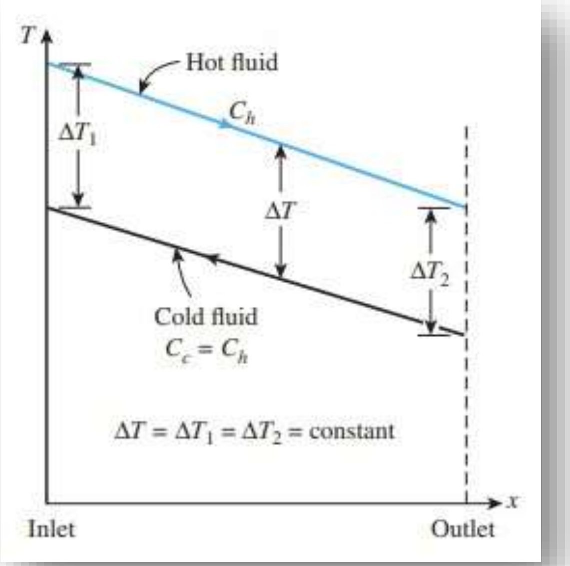


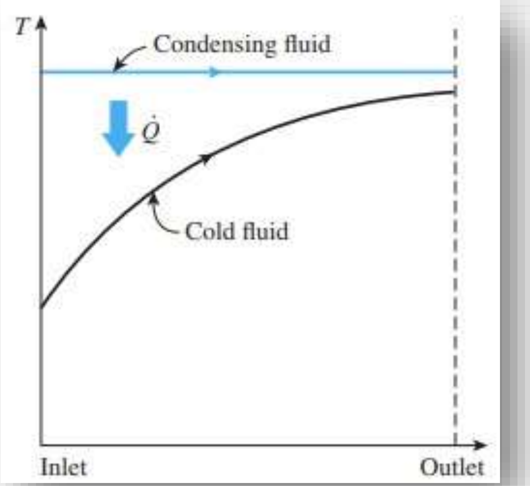


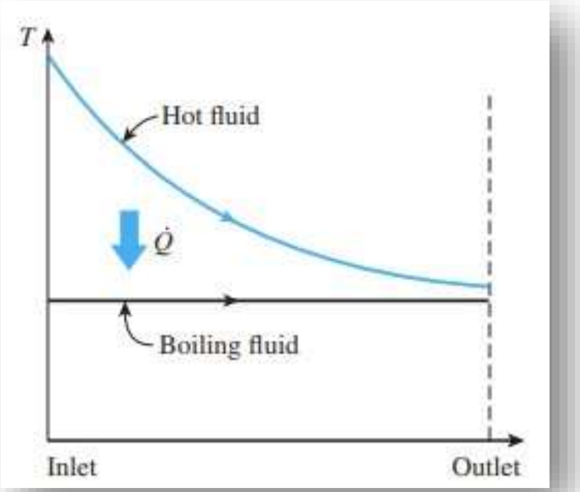
ANALYSIS OF HEAT EXCHANGERS

- Selection of Heat Exchanger
  - Specified Temperature Difference (Hot/Cold)
  - Specified Flow Rate
  - Specified Heat Transfer

$$Q = m\ C_p \Delta T_m$$

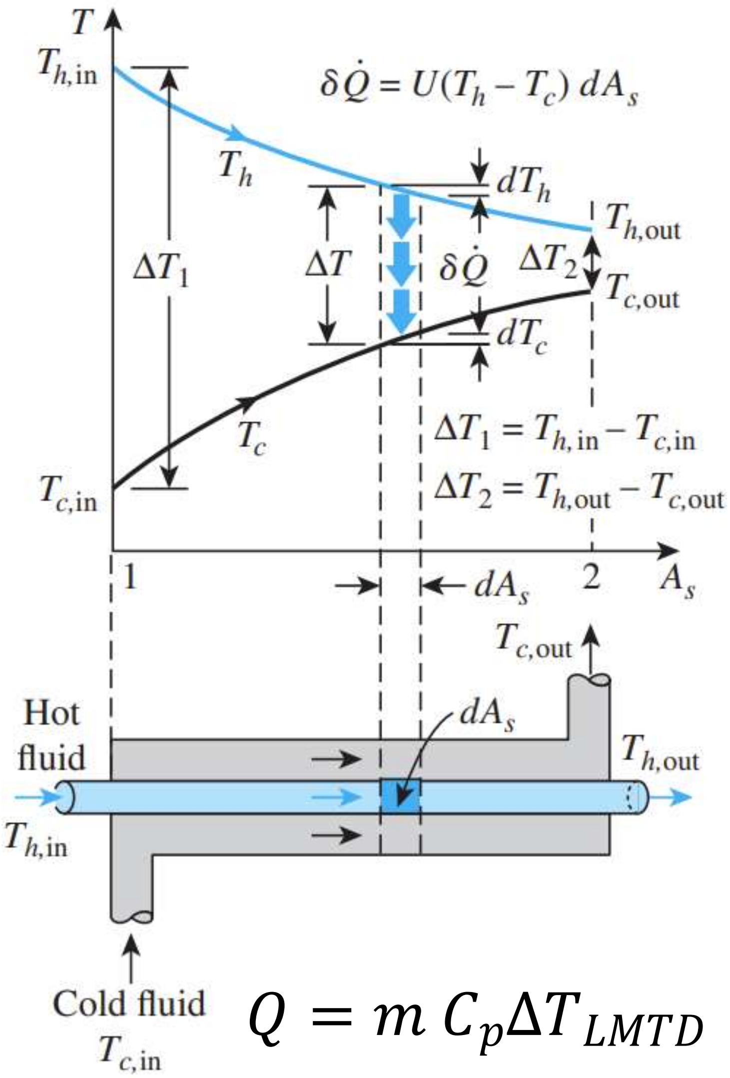






LOG MEAN TEMPERATURE DIFFERENCE METHOD

Parallel Flow Heat Exchanger



$$Q = m\, C_p \Delta T_{LMTD}$$

Heat Transfer @ Small Segment

$$Q = h\, A\, (T_h - T_c)$$

$$Q = U\, A\, (T_h - T_c)$$

$$dQ = U\, dA\, (\Delta T)$$

Apply Energy Balance Equation

$$dQ = -m_h C_h\ (T_{hi} - T_{ho}) = m_c C_c\ (T_{co} - T_{ci})$$

$$Q = C_h\ (dT_h) = C_c\ (dT_c)$$

$$dT_h = -\frac{dQ}{C_h} \qquad dT_c = \frac{dQ}{C_c}$$

$$dT = (dT_h)\ - (dT_c)$$

$$dT = \left(-\frac{dQ}{C_h}\right) - \left(\frac{dQ}{C_c}\right)$$

$$dT = \left(-\frac{U\, dA\, (\Delta T)}{C_h}\right) - \left(\frac{U\, dA\, (\Delta T)}{C_c}\right)$$

$$dT = U\, dA\, (\Delta T)\left(-\frac{1}{C_h}\right) - \left(\frac{1}{C_c}\right)$$

Rearrange & Integrate

$$\frac{dT}{(\Delta T)} = -U\ \left(\frac{1}{C_h}\right) + \left(\frac{1}{C_c}\right) dA$$

$$\int_{\Delta T_1}^{\Delta T_2} \frac{dT}{(\Delta T)} = -U\ \left(\frac{1}{C_h}\right) + \left(\frac{1}{C_c}\right) \int dA$$

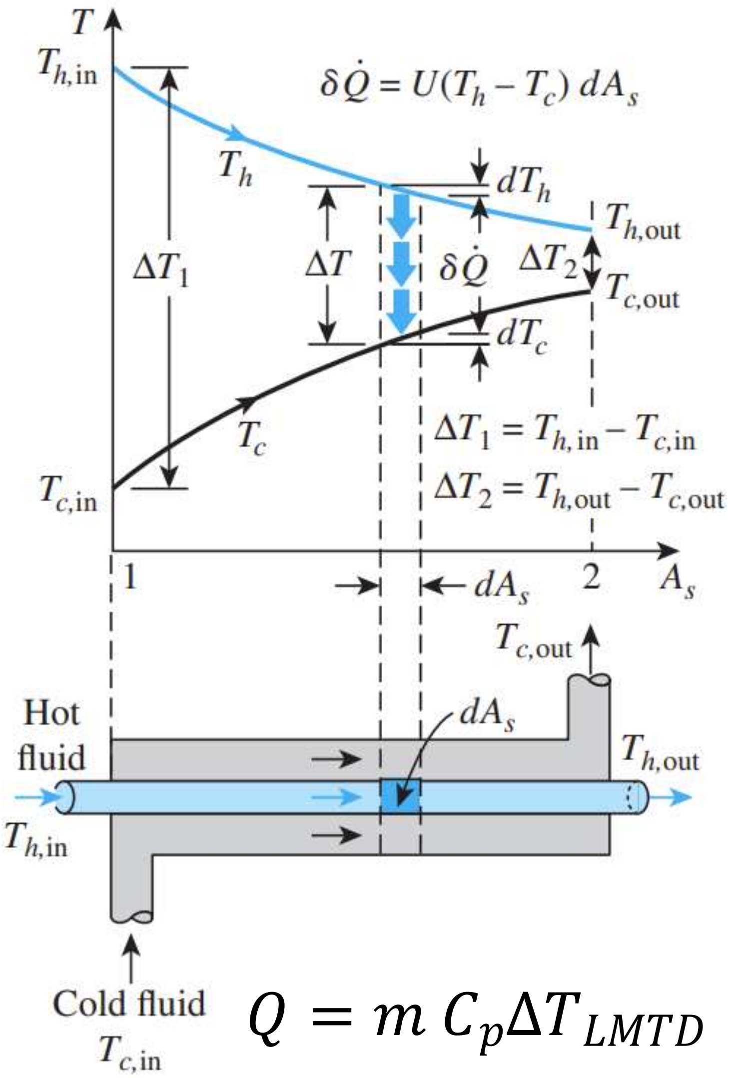
$$\ln\left[\frac{\Delta T_2}{\Delta T_1}\right] = -UA\left(\frac{1}{C_h}\right) + \left(\frac{1}{C_c}\right)$$

$$\ln\left[\frac{\Delta T_1}{\Delta T_2}\right] = UA\ \left(\frac{dT_h}{Q}\right) + \left(\frac{dT_c}{Q}\right)$$

$$\ln\left[\frac{\Delta T_1}{\Delta T_2}\right] = \frac{UA}{Q}(T_{hi} - T_{ho}) + (T_{co} - T_{ci})$$

$$\ln\left[\frac{\Delta T_1}{\Delta T_2}\right] = \frac{UA}{Q}\ (T_{hi} - T_{ci}) - (T_{ho} - T_{co})$$

LOG MEAN TEMPERATURE DIFFERENCE METHOD



$$Q = m\, C_p \Delta T_{LMTD}$$

Heat Transfer @ Small Segment

$$\ln\left[\frac{\Delta T_1}{\Delta T_2}\right] = \frac{UA}{Q}(T_{hi} - T_{ci}) - (T_{ho} - T_{co})$$

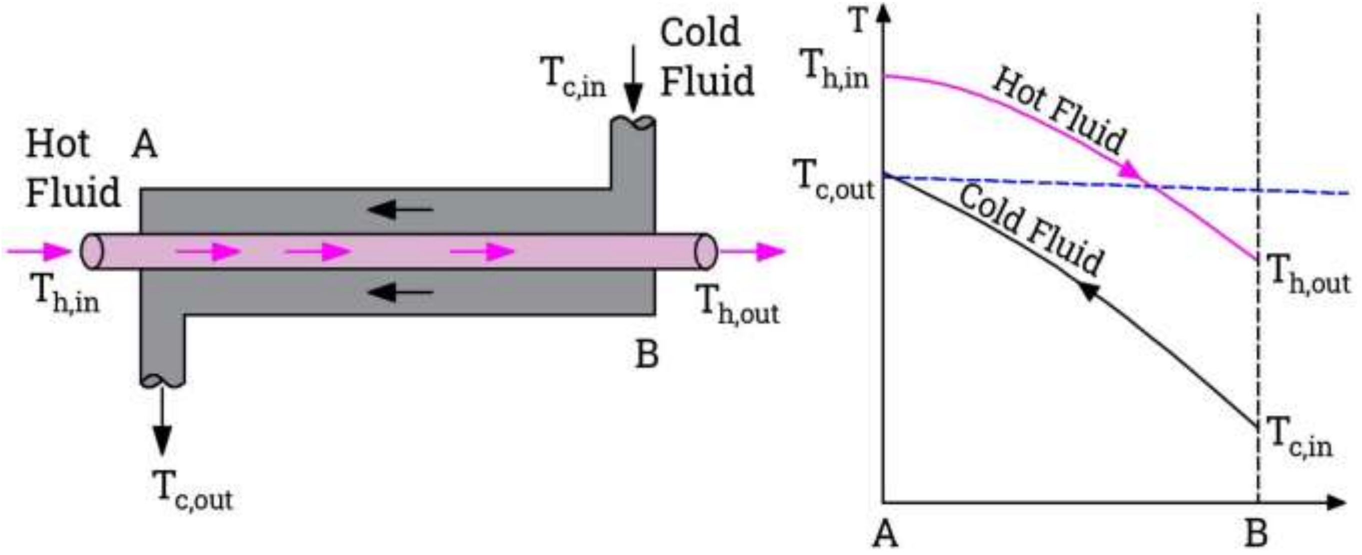
$$\ln\left[\frac{\Delta T_1}{\Delta T_2}\right] = \frac{UA}{Q}(\Delta T_1) - (\Delta T_2)$$

$$Q = UA\,\frac{(\Delta T_1) - (\Delta T_2)}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]}$$

$$Q = UA(LMTD)$$

LOG MEAN TEMPERATURE DIFFERENCE METHOD

Counter Flow Heat Exchanger

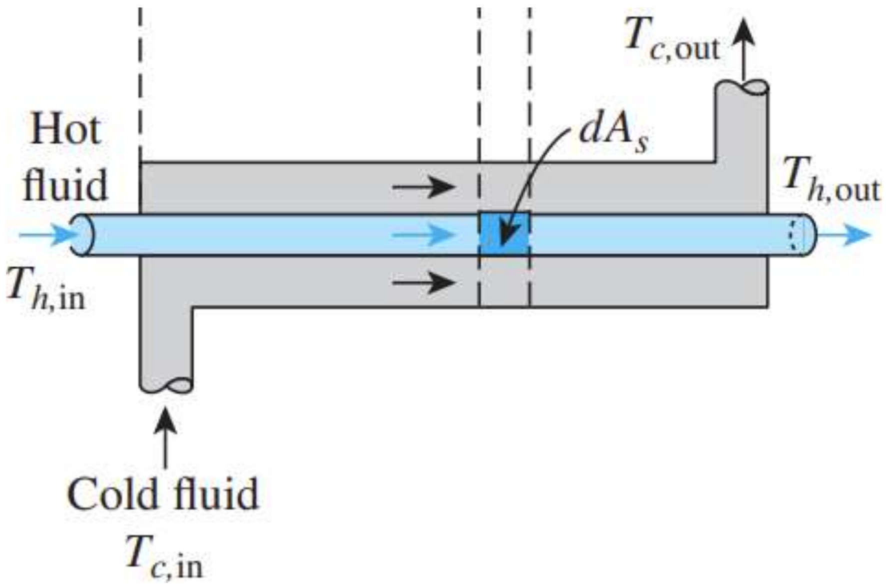


$$Q = UA\frac{(\Delta T_1) - (\Delta T_2)}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]}$$

$\Delta T_1 = T_{hi} - T_{co}$

$\Delta T_2 = T_{ho} - T_{ci}$

NUMBER OF TRANSFER UNITS (NTU) METHOD



$C_h = m_h c_h \qquad C_c = m_c c_c \qquad C_{min}$ & C_{max}

$$NTU = \frac{UA}{C_{min}}$$

$$Effectiveness \in = \frac{Q_{act}}{Q_{max}}$$

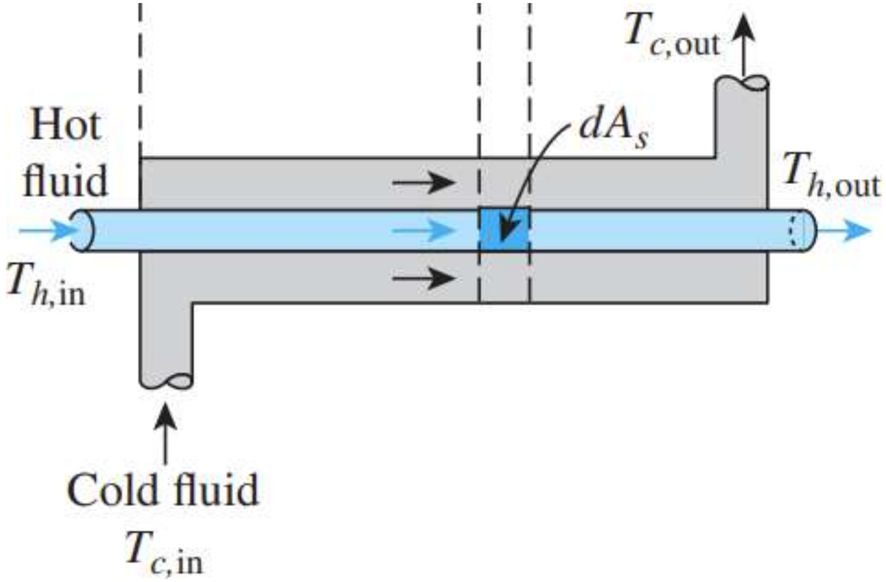
$$Q_{act} = C_c\,(T_{co} - T_{ci}) = C_h\,(T_{hi} - T_{ho})$$

$$Q_{max} = C_{min}\,(T_{hi} - T_{ci})$$

$$Effectiveness \in = \frac{C_c\,(T_{co} - T_{co})}{C_{min}\,(T_{hi} - T_{ci})} = \frac{C_h\,(T_{hi} - T_{ho})}{C_{min}\,(T_{hi} - T_{ci})}$$

- LMTD – for 4 known temperatures
- NTU - for 3 Known Temperatures

NUMBER OF TRANSFER UNITS (NTU) METHOD



$C_h = m_h c_h$ $\quad$ $C_c = m_c c_c$ $\quad$ C_{min} & C_{max}

$$NTU = \frac{UA}{C_{min}}$$

$$Effectiveness \in = \frac{Q_{act}}{Q_{max}}$$

$$Q_{act} = C_c \,(T_{co} - T_{ci}) = C_h \,(T_{hi} - T_{ho})$$

$$Q_{max} = C_{min} \,(T_{hi} - T_{ci})$$

$$Effectiveness \in = \frac{C_c \,(T_{co} - T_{co})}{C_{min} \,(T_{hi} - T_{ci})} = \frac{C_h \,(T_{hi} - T_{ho})}{C_{min} \,(T_{hi} - T_{ci})}$$

- LMTD – for 4 known temperatures
- NTU - for 3 Known Temperatures

RECAP . . .

- Device that Felicitates Heat Transfer by Structured Flow
- Design Relies on Flow, HT Geometry, Fluid & So on
- Shell and Tube Heat Exchangers – Commonly Used
- LMTD – Better Analytical method Over Mean Temp Method
- LMTD Good to Estimate the Heat Transfer
- NTU Good to Estimate the Effectiveness