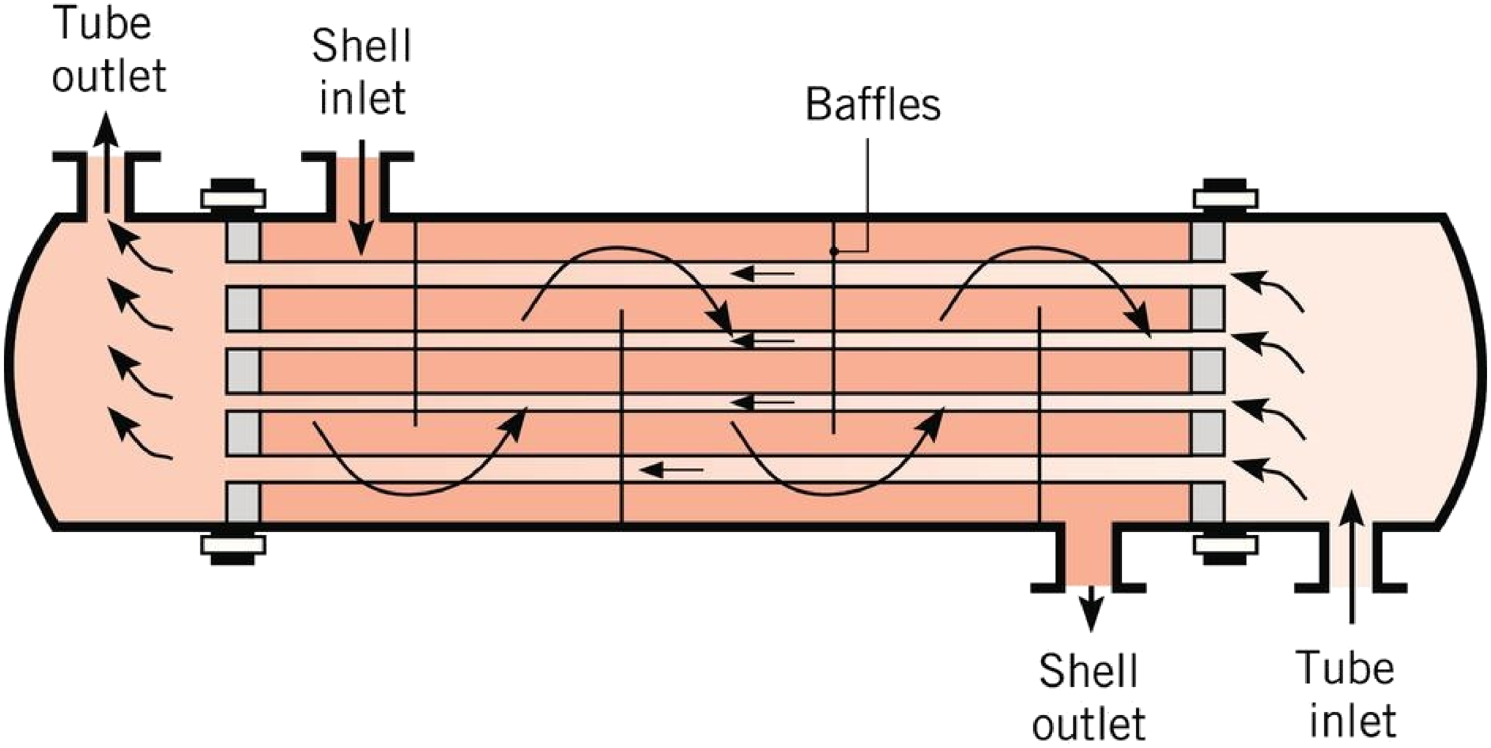
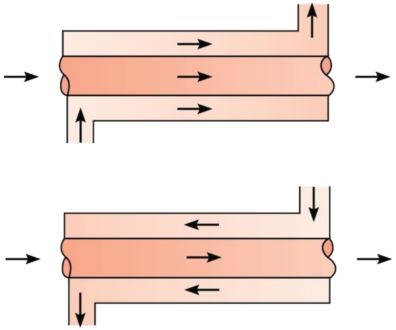
Heat Exchangers

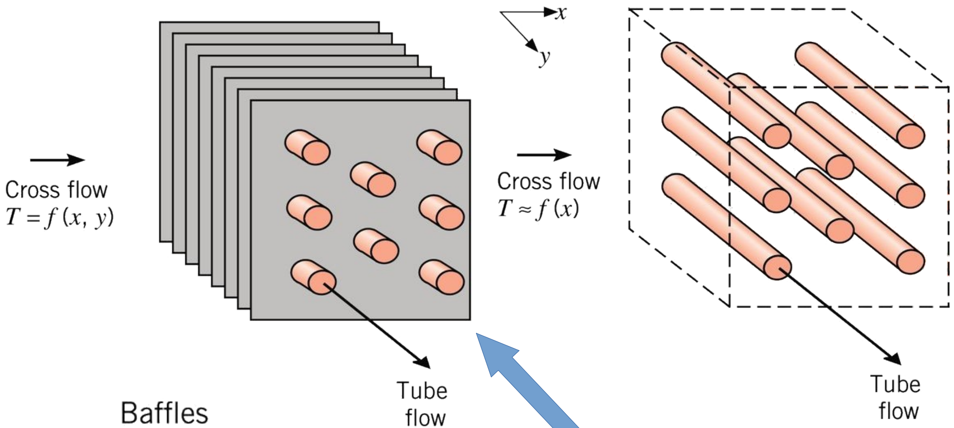


Introduction

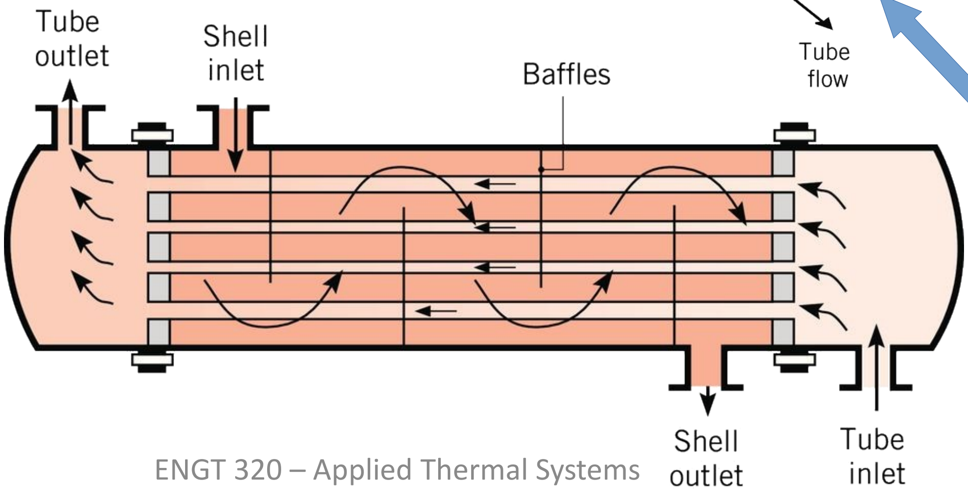
- Heat exchanger – A device that exchanges heat between two fluids that are different temperatures separated by a solid wall.

- 3 main types:
  - Concentric tube
  - Cross flow
  - Shell and tube





- 2 types of flow:
  - Parallel
  - Counter



Known also as fin and tube.

Heat Exchanger

- The Overall Heat Transfer Coefficient
$$\frac{1}{UA}=\frac{1}{U_c A_c}=\frac{1}{U_h A_h}=\frac{1}{(hA)_c}+R_w+\frac{1}{(hA)_h}$$
where c and h refer to the cold and hot fluids, respectively.
- This form only applies to clean, unfinned heat exchangers.
- Once in operation, dirt and corrosion collect on the surfaces.
- This is known as fouling and is described by a fouling factor R_f.
- The Overall Heat Transfer Coefficient then becomes
$$\frac{1}{UA}=\frac{1}{(\eta_o hA)_c}+\frac{R''_{f,c}}{(\eta_o A)_c}+R_w+\frac{R''_{f,h}}{(\eta_o A)_h}+\frac{1}{(\eta_o hA)_h}$$
- This for accounts for fins as well as fouling.

Typical Fouling Factors

Table 11.1

Fluid	R''_f $(m^2 \cdot K/W)$
Seawater and treated boiler feedwater (below 50°C)	0.0001
Seawater and treated boiler feedwater (above 50°C)	0.0002
River water (below 50°C)	0.0002–0.001
Fuel oil	0.0009
Refrigerating liquids	0.0002
Steam (nonoil bearing)	0.0001

Heat Exchanger Analysis

- 2 main approaches
  - Log mean temperature difference method
  - Effectiveness-NTU method
- Log mean temperature difference method is useful when inlet and outlet conditions are known.
- However, when only inlet conditions are known, the Effectiveness-NTU method is preferred due to the avoidance of an iterative approach.

Log Mean ΔT Method

- Consider the arrangement below.
- For a cold and hot fluid, the heat rate is given by

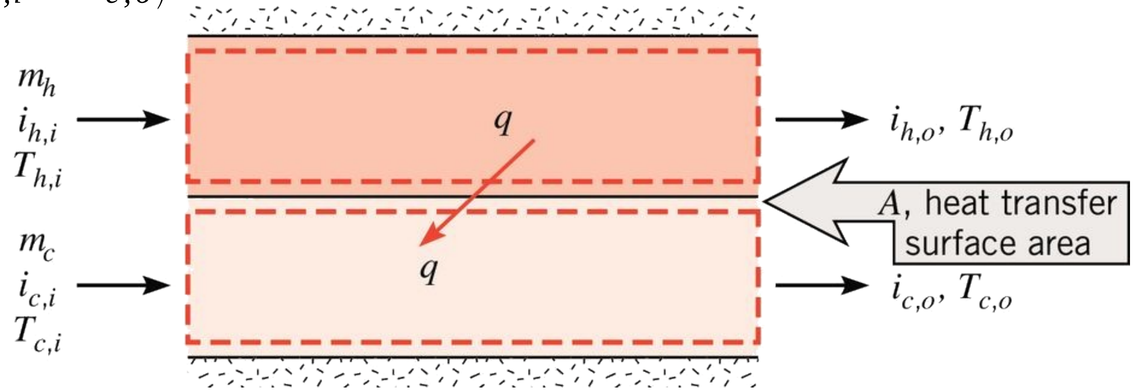
  $$q = m_h \left(i_{h,i} - i_{h,o} \right) \qquad q = m_c \left(i_{c,i} - i_{c,o} \right)$$

  where i is enthalpy.
- For a cold and hot fluid that does not undergo a phase change

  $$q = m_h c_{p,h} \left(T_{h,i} - T_{h,o} \right) \qquad q = m_c c_{p,c} \left(T_{c,i} - T_{c,o} \right)$$

- Another useful expression is

  $$q = U A \Delta T_m$$



Log Mean ΔT Method: Parallel Flow

- A parallel flow arrangement is shown to the right.
- The heat rate is given by
  $q = U A \Delta T_{lm}$
  where

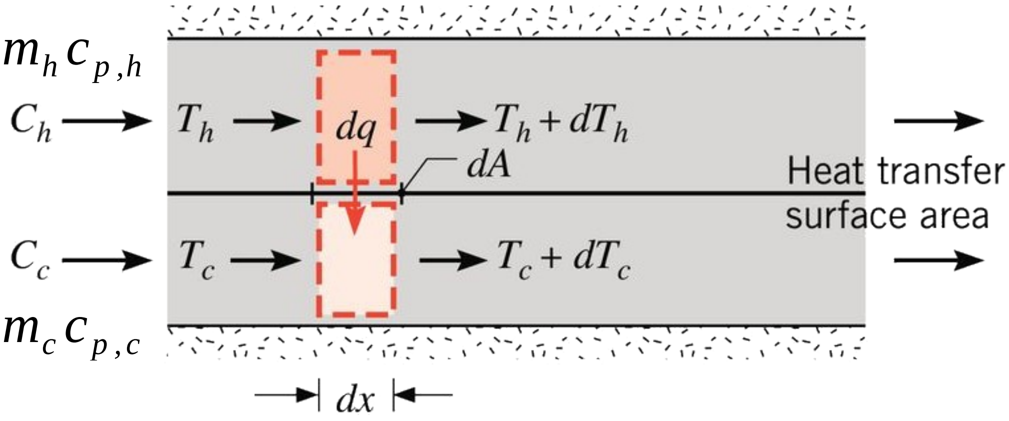
$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln \frac{\Delta T_2}{\Delta T_1}} = \frac{\Delta T_1 - \Delta T_2}{\ln \frac{\Delta T_1}{\Delta T_2}}$$

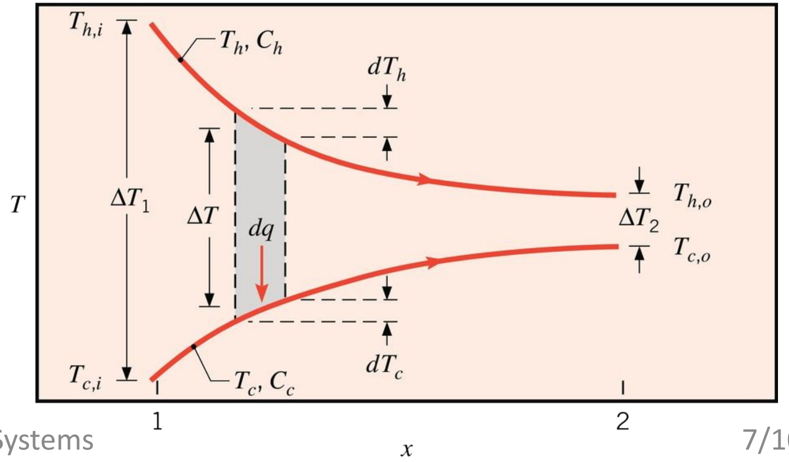
$$\Delta T_1 \equiv T_{h,1} - T_{c,1} = T_{h,i} - T_{c,i}$$

$$\Delta T_2 \equiv T_{h,2} - T_{c,2} = T_{h,o} - T_{c,o}$$

$C_h = m_h c_{p,h}$

$C_c = m_c c_{p,c}$





Example 1

A concentric tube heat exchanger operating in parallel flow uses hot exhaust gases to heat water from 30 to $80\ °C$ at a rate of $3\ kg/s$. The exhaust gases, having thermophysical properties similar to air, enter and exit the exchanger at 225 and $100\ °C$, respectively. The thin walled separator tube has a diameter of $100\ mm$. If the overall heat transfer coefficient is $200\ W/m^2K$, estimate the required surface area. Determine the required length for the exchanger.

Log Mean ΔT Method: Counter Flow

- A counter flow arrangement is shown to the right.
- The heat rate is given by

  $$q = U A \Delta T_{lm}$$

  where

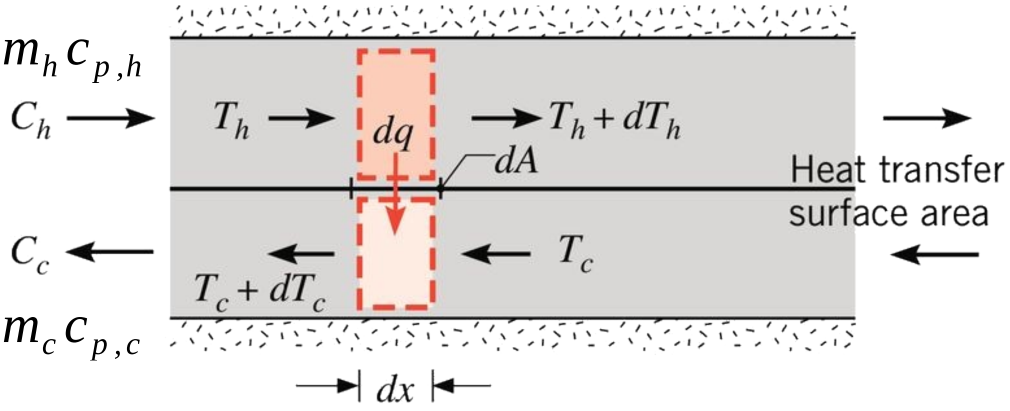
$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln \dfrac{\Delta T_2}{\Delta T_1}} = \frac{\Delta T_1 - \Delta T_2}{\ln \dfrac{\Delta T_1}{\Delta T_2}}$$

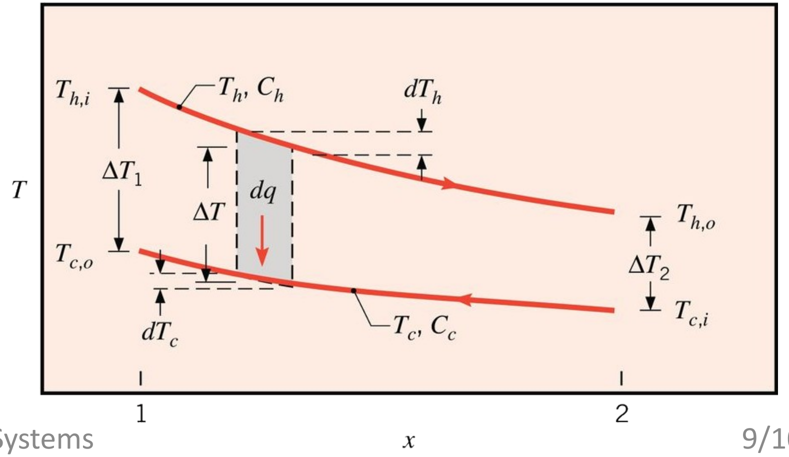
$$\Delta T_1 \equiv T_{h,1} - T_{c,1} = T_{h,i} - T_{c,o}$$

$$\Delta T_2 \equiv T_{h,2} - T_{c,2} = T_{h,o} - T_{c,i}$$

$$C_h = m_h c_{p,h}$$

$$C_c = m_c c_{p,c}$$





Example 2

A counter flow, 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 $60\ °C$?