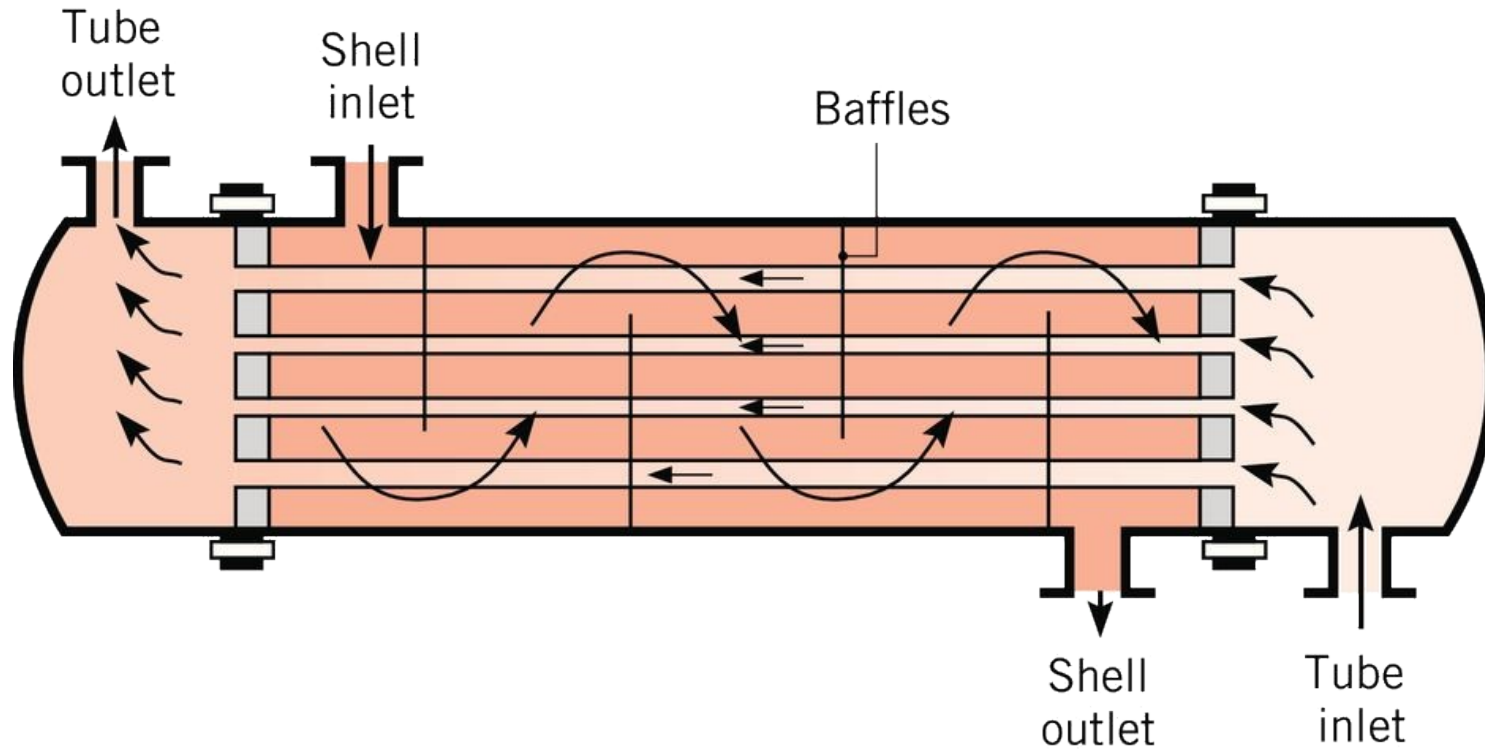


Heat Exchangers



Introduction

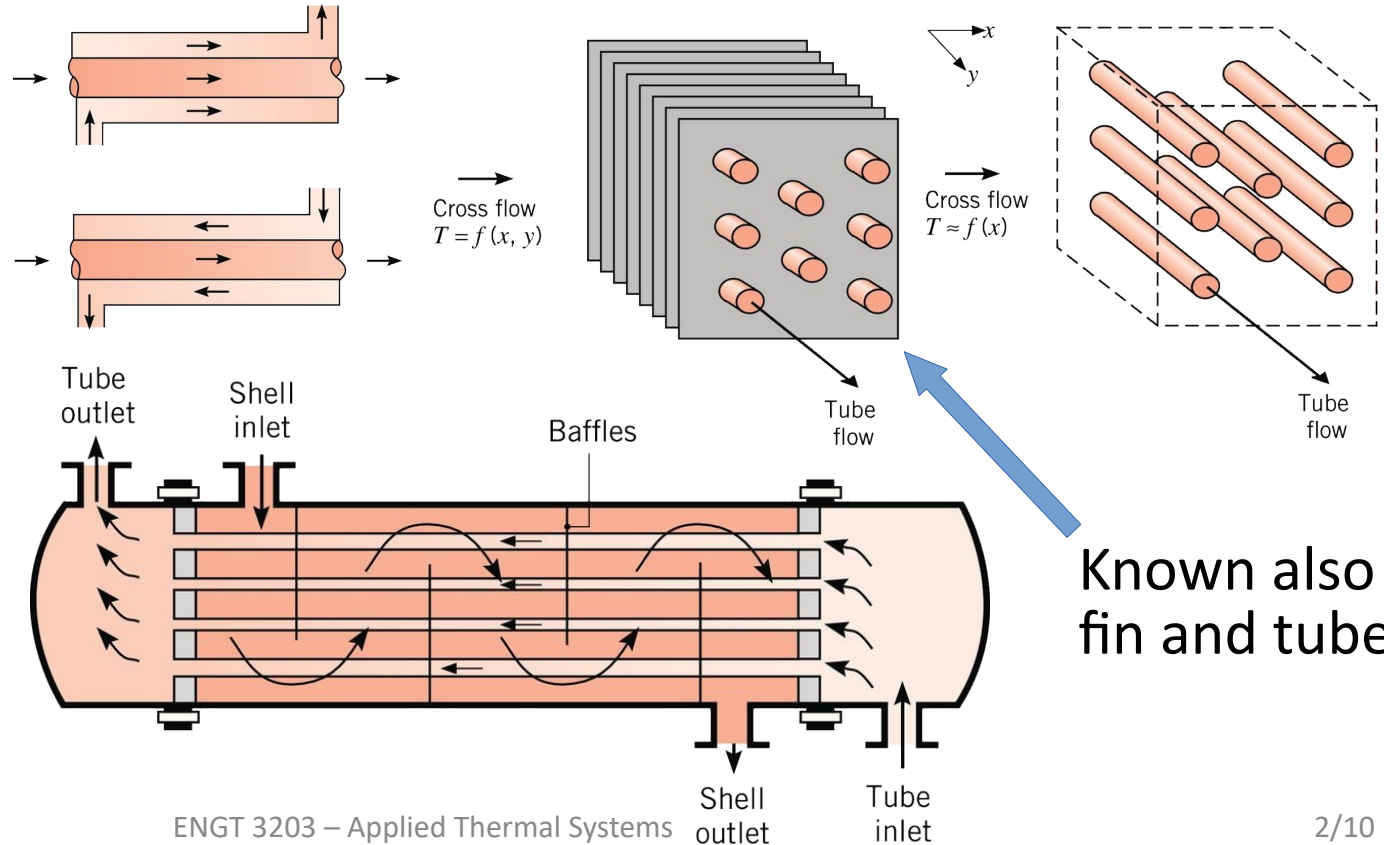
- Heat exchanger – A device that exchanges heat between two fluids that are different temperatures separated by a solid wall.

- 3 main types:

- Concentric tube
- Cross flow
- Shell and tube

- 2 types of flow:

- Parallel
- Counter



Heat Exchanger

- The Overall Heat Transfer Coefficient

$$\frac{1}{UA} = \frac{1}{U_c A_c} = \frac{1}{U_h A_h} = \frac{1}{(h A)_c} + R_w + \frac{1}{(h A)_h}$$

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

$$\frac{1}{U A} = \frac{1}{(\eta_o h A)_c} + \frac{R_{f,c}''}{(\eta_o A)_c} + R_w + \frac{R_{f,h}''}{(\eta_o A)_h} + \frac{1}{(\eta_o h A)_h}$$

- This formula accounts for fins as well as fouling.

Typical Fouling Factors

Table 11.1

Fluid	R_f'' ($\text{m}^2 \cdot \text{K}/\text{W}$)
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

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

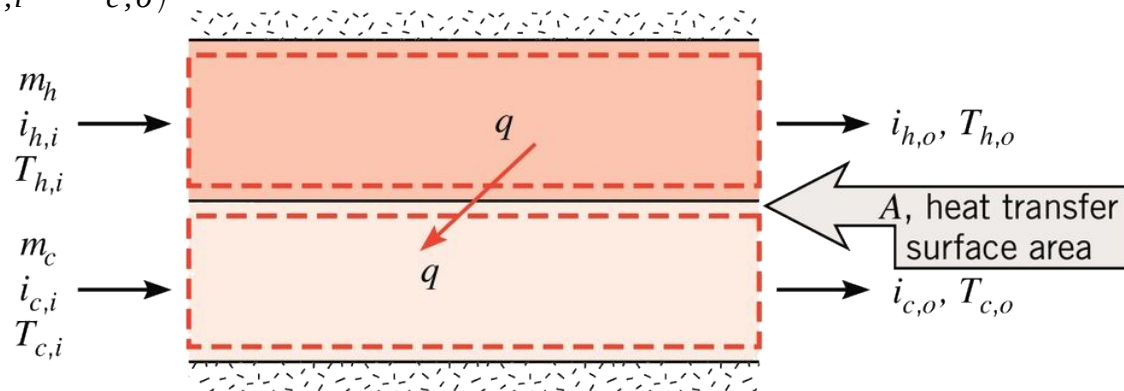
where i is enthalpy.

- For a cold and hot fluid that does not undergo a phase change

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

- 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

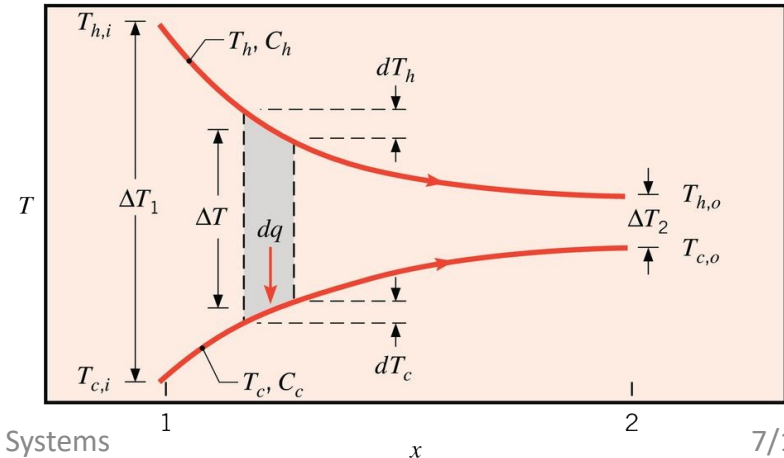
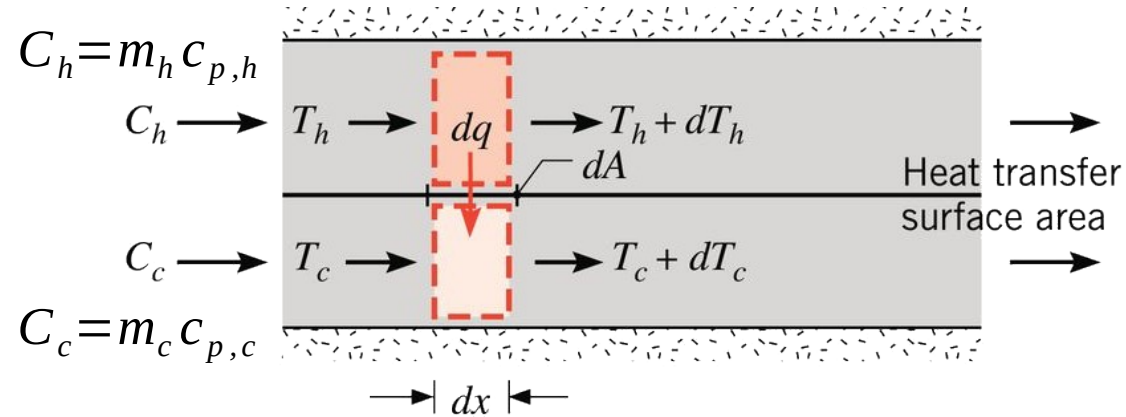
$$q = U A \Delta T_{lm}$$

where

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

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

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



Example 1

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

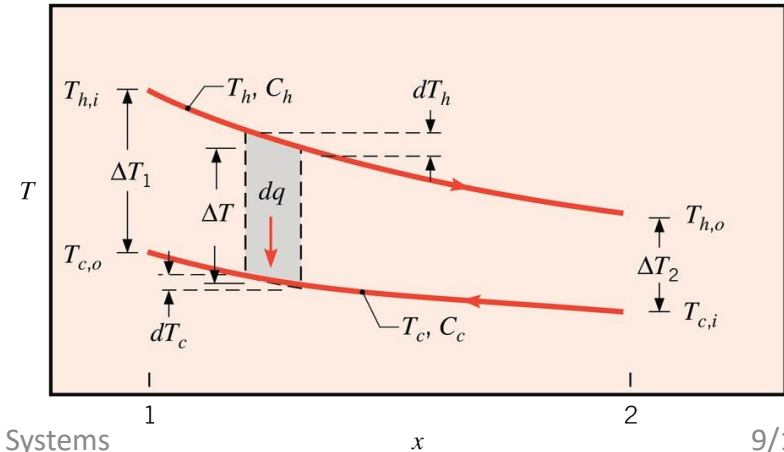
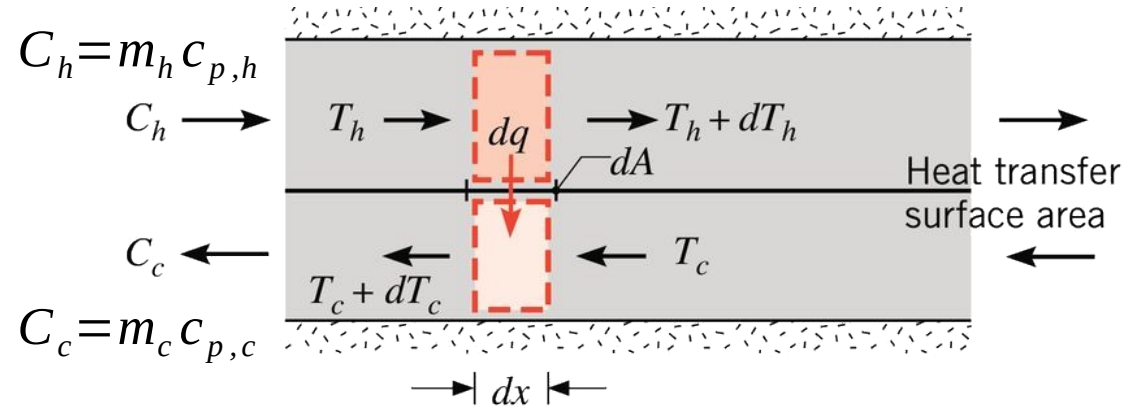
$$q = U A \Delta T_{lm}$$

where

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

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

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



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 ($D_i = 25 \text{ mm}$) is 0.2 kg/s , while the flow rate of oil through the outer annulus ($D_o = 45 \text{ mm}$) is 0.1 kg/s . The oil and water enter at temperatures of 100 and $30 \text{ }^\circ\text{C}$, respectively. How long must the tube be made if the outlet temperature of the oil is to be $60 \text{ }^\circ\text{C}$?