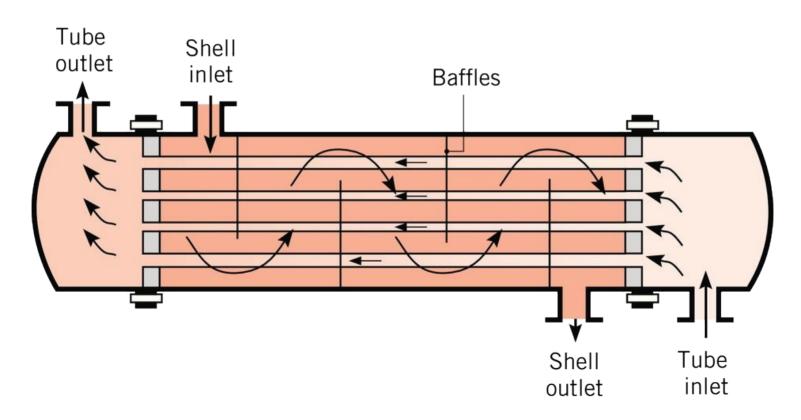
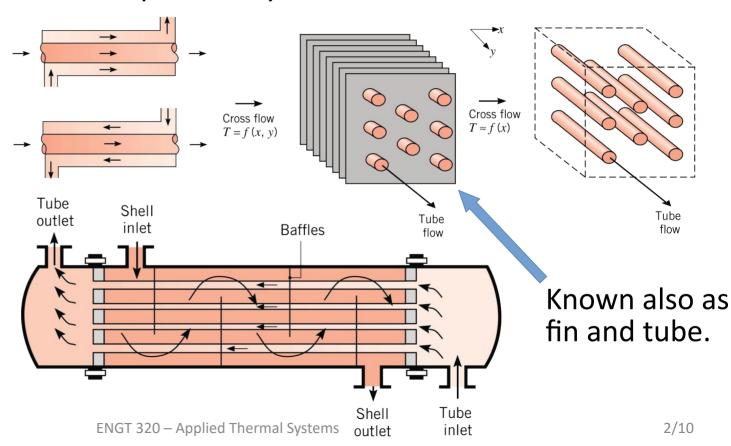
Heat Exchangers



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

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

• This formula accounts for fins as well as fouling.

Typical Fouling Factors

Table 11.1

| Fluid | $R_f''(\mathbf{m}^2 \cdot \mathbf{K}/\mathbf{W})$ |
|--|---|
| 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 **\Delta T** Method

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

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

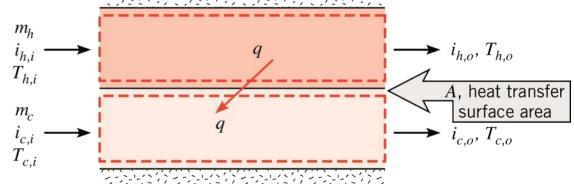
where *i* is enthalpy.

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

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

Another useful expression is

$$q = U A \Delta T_m$$

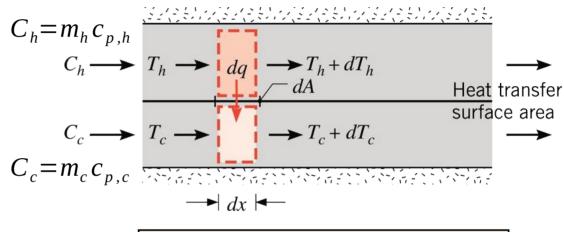


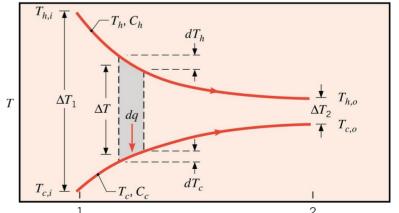
Log Mean ΔT Method: Parallel Flow

- 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

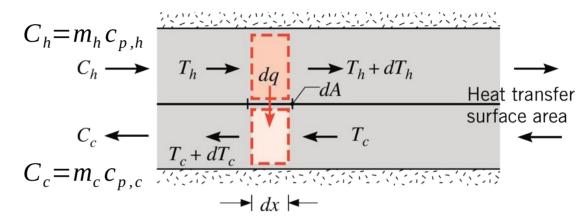
A concentric tube heat exchanger operating in parallel flow uses hot exhaust gases to heat water from 30 to 80 °C at a rate of 3 kg/s. The exhaust gases, having thermophysical properties similar to air, enter and exit the exchanger at 225 and 100 °C, respectively. The thin walled separator tube has a 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.

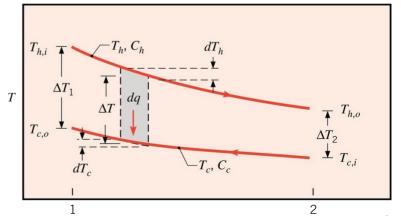
Log Mean ΔT Method: Counter Flow

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

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

$$\Delta T_1 \equiv T_{h,1} - T_{c,1} = T_{h,i} - T_{c,o}$$
$$\Delta T_2 \equiv T_{h,2} - T_{c,2} = T_{h,o} - T_{c,i}$$





 \boldsymbol{x}

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 °C, respectively. How long must the tube be made if the outlet temperature of the oil is to be 60 °C?