Module

4

Lecture

4

Asansol Engineering College
Department of Mechanical Engineering

Thermodynamics

First Law for Flow Processes

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Topics to be discussed in present lecture

- **Heat Exchangers**
- **Solved Example on Heat Exchanger**
- **Boilers, Condensers, and Evaporators**
- **Mixing Chambers**

Heat Exchangers

- ***Heat exchangers*** are devices where two moving fluid streams exchange heat without mixing.
- Heat exchangers are widely used in various industries, and they come in various designs.
- The simplest form of a heat exchanger is a *double-tube* (also called *tube and-shell*) *heat exchanger,* shown in Fig. 4.13.
- It is composed of two concentric pipes of different diameters.
- One fluid flows in the inner pipe, and the other in the annular space between the two pipes.
- Heat is transferred from the hot fluid to the cold one through the wall separating them.
- Sometimes the inner tube makes a couple of turns inside the shell to increase the heat transfer area, and thus the rate of heat transfer.
- Under steady operation, the mass flow rate of each fluid stream flowing through a heat exchanger remains constant.

Heat Exchangers (*Contd…*)

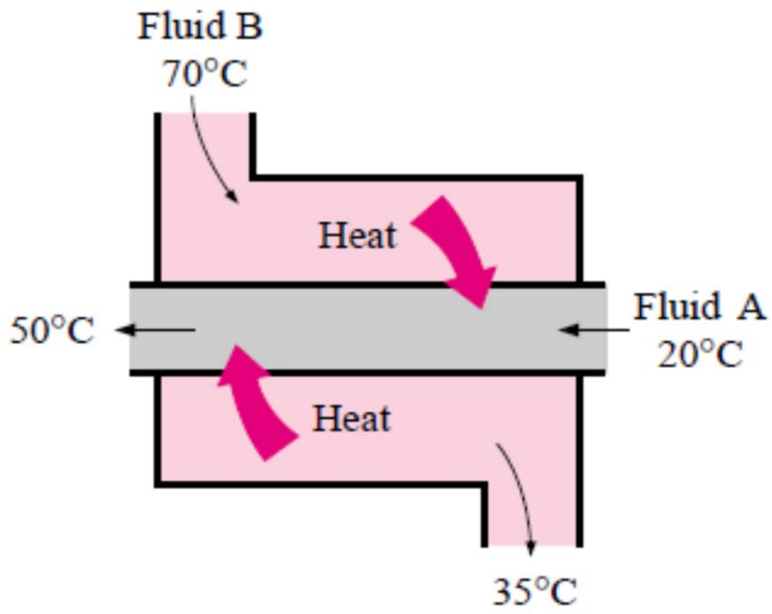
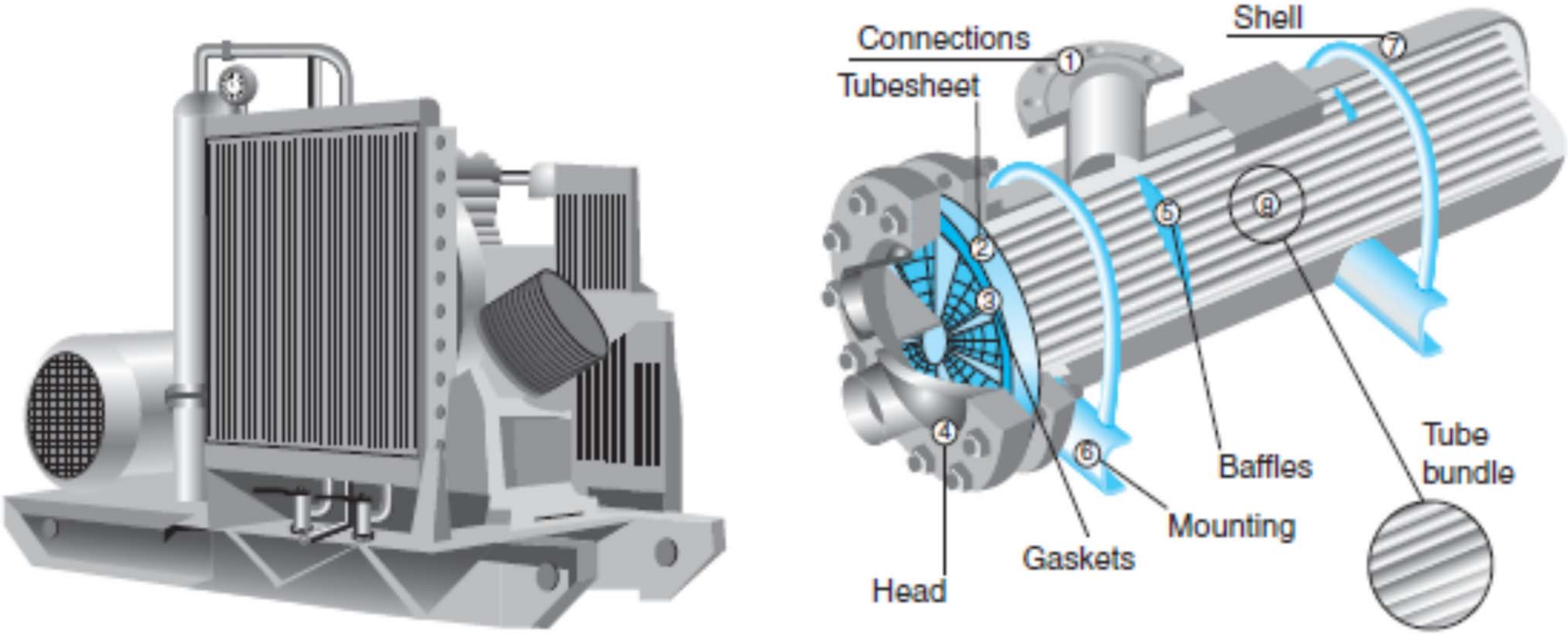


Fig. 4.13: A heat exchanger can be as simple as two concentric pipes.

Heat Exchangers (*Contd…*)



(*a*) An aftercooler for a diesel engine

(*b*) A shell and tube heat exchanger

Fig. 4.14: Examples of heat exchangers

Heat Exchangers (*Contd…*)

Assumptions: (1) constant volume, W = 0

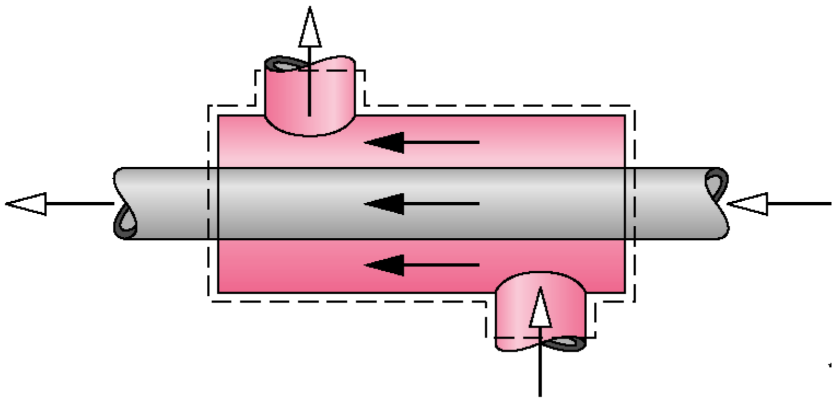
(2) change in potential energy negligible

(3) steady-state, d/dt = 0

(4) change in kinetic energy negligible

(5) adiabatic, Q = 0

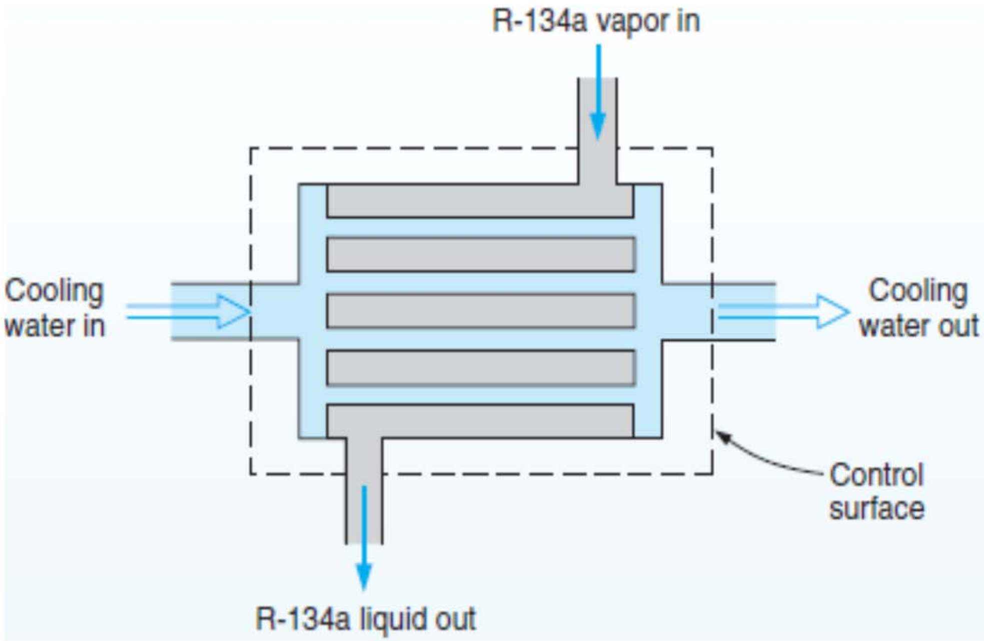
$$\cancel{\frac{dE_{CV}}{dt}} = \cancel{\dot{Q}} - \cancel{\dot{W}} + \sum \dot{m}_{in}\left(h_{in} + \cancel{\frac{V_{in}^2}{2}} + \cancel{gz_{in}}\right) - \sum \dot{m}_{out}\left(h_{out} + \cancel{\frac{V_{out}^2}{2}} + \cancel{gz_{out}}\right)$$



$$\boxed{\sum \dot{m}_{in} h_{in} = \sum \dot{m}_{out} h_{out}}$$

Example 4.4

Consider a water-cooled condenser in a large refrigeration system in which R-134a is the refrigerant fluid. The refrigerant enters the condenser at 1.0 MPa and 60°C, at the rate of 0.2 kg/s, and exits as a liquid at 0.95 MPa and 35°C. Cooling water enters the condenser at 10°C and exits at 20°C. Determine the rate at which cooling water flows through the condenser.



The steady-state energy equation is

$$\sum \dot{m}_i h_i = \sum \dot{m}_e h_e$$

Using the subscripts r for refrigerant and w for water, we write

$$\dot{m}_r (h_i)_r + \dot{m}_w (h_i)_w = \dot{m}_r (h_e)_r + \dot{m}_w (h_e)_w$$

From the R-134a and steam tables, we have

$$(h_i)_r = 441.89\ \text{kJ/kg}, \qquad (h_i)_w = 42.00\ \text{kJ/kg}$$

$$(h_e)_r = 249.10\ \text{kJ/kg}, \qquad (h_e)_w = 83.95\ \text{kJ/kg}$$

Solving the above equation for $\dot{m}_w$, the rate of flow of water, we obtain

$$\dot{m}_w = \dot{m}_r \frac{(h_i - h_e)_r}{(h_e - h_i)_w} = 0.2\ \text{kg/s} \frac{(441.89 - 249.10)\ \text{kJ/kg}}{(83.95 - 42.00)\ \text{kJ/kg}} = 0.919\ \text{kg/s}$$

This problem can also be solved by considering two separate control volumes, one having the flow of R-134a across its control surface and the other having the flow of water across its control surface. Further, there is heat transfer from one control volume to the other.

The heat transfer for the control volume involving R-134a is calculated first. In this case the steady-state energy equation reduces to

$$\dot{Q}_{\text{C.V.}} = \dot{m}_r(h_e - h_i)_r$$
$$= 0.2\ \text{kg/s} \times (249.10 - 441.89)\ \text{kJ/kg} = -38.558\ \text{kW}$$

This is also the heat transfer to the other control volume, for which $\dot{Q}_{\text{C.V.}} = +38.558\ \text{kW}$.

$$\dot{Q}_{\text{C.V.}} = \dot{m}_w(h_e - h_i)_w$$

$$\dot{m}_w = \frac{38.558\ \text{kW}}{(83.95 - 42.00)\ \text{kJ/kg}} = 0.919\ \text{kg/s}$$

Boilers, Condensers, and Evaporators

Assumptions: (1) constant volume, W = 0
(2) change in potential energy negligible
(3) steady-state, d/dt = 0
(4) change in kinetic energy negligible

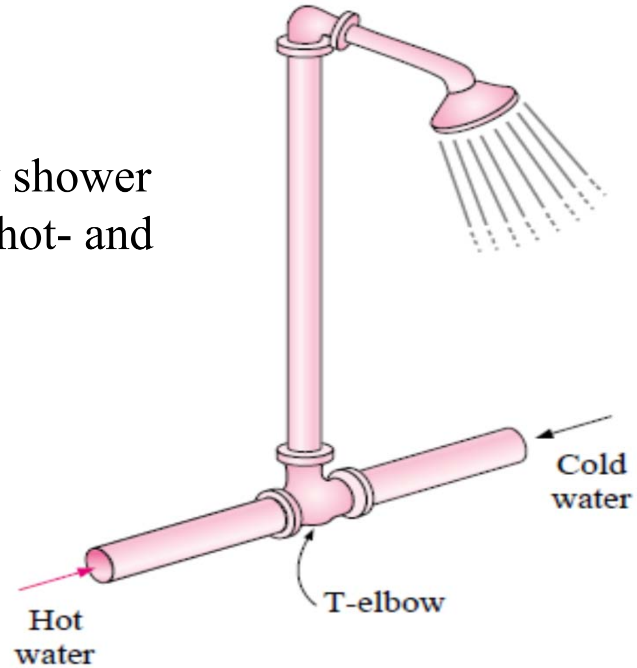
$$\cancel{\frac{dE_{C\forall}}{dt}} = \dot{Q} - \cancel{\dot{W}} + \sum \dot{m}_{in}\left(h_{in} + \cancel{\frac{V_{in}^2}{2}} + \cancel{gz_{in}} \right) - \sum \dot{m}_{out}\left(h_{out} + \cancel{\frac{V_{out}^2}{2}} + \cancel{gz_{out}} \right)$$

$$\boxed{\frac{\dot{Q}}{\dot{m}} = h_{out} - h_{in}}$$

Mixing Chambers

- Mixing two streams of fluids is common in engineering applications.
- The section where the mixing process takes place is commonly referred to as a *mixing chamber*.
- An ordinary T-elbow or a Y-elbow in a shower, for example, serves as the mixing chamber for the cold- and hot-water streams (Fig. 4.13).

Fig. 4.13: The T-elbow of an ordinary shower serves as the mixing chamber for the hot- and the cold-water streams.



- The conservation of mass principle for a mixing chamber requires that the sum of the incoming mass flow rates equal the mass flow rate of the outgoing mixture.
- Mixing chambers are usually well insulated ($q = 0$) and do not involve any kind of work ($w = 0$). Also, the kinetic and potential energies of the fluid streams are usually negligible (ke = 0, pe = 0).

- Then all there is left in the energy balance is the total energies of the incoming streams and the outgoing mixture.

- The conservation of energy principle requires that these two equal each other.

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Topics to be discussed in next lecture

- **Transient Processes**
- **Solved Example on Transient Processes**

Thank You