Double Pipe Heat Exchanger
CE 328
Spring 2005

Objective:

To study and evaluate the effects of hot and cold fluid flow rate and flow configurations on the rate of heat transfer through thin walled tubes. To determine the overall heat transfer coefficient for the double pipe heat exchanger for countercurrent flow and parallel (or co-current) flow.

System:

The heat exchanger consists of two thin wall copper tubes mounted concentrically on a panel. The flow of water through the center tube can be reversed for either countercurrent or parallel flow. The hot water flows through the center tube, and cold water flows in the annular region.

- Valves are used to set up desired flow conditions (rate and direction). Set the hot water valve in the correct position to achieve either countercurrent or parallel flow.
- Thermometers and thermocouples are placed near the entrance, midpoint and exit of each pipe. The thermometer should give coarse readings compared to the thermocouple. The thermocouples are connected to a selector switch on the front of the panel.
- The flow meter has a direct read scale in ft^3/min. The flow meter does not read zero at zero flow due to rubber offset. The flow meter can read either the cold or hot water flow rate by turning the appropriate valves.
- A synopsis of operation is as follows: Open or close the appropriate valves to set hot water flow at 0.2 ft3/min in countercurrent configuration. (All globe valves should be totally opened or totally closed.) The metering valves at the outlets should be used to control flow rates. Before beginning cold water flow, temporarily close valve#1 to conserve hot water. Set valve positions for cold water flow at 1.0 ft3/min, then resume hot water flow (open valve#1) Allow the system to reach steady state before taking measurements (1-2 min). Take at least three readings of temperature and cold water flow before changing to new cold water flow rate. Examine cold water flows of 0.8 ft3/min and 0.6 ft3/min. **The two heat exchanger groups must work together once the flow has been initiated because the adjustment of flow in one group will affect the other team's flows. You must communicate when you are ready to change flow rates**. Once you have taken readings for all three rates of cold water flow, reverse the direction of the hot water flow (to the parallel flow configuration) by opening and closing appropriate hot water valves. Collect parallel flow data at cold water flow rate of 0.6 ft3/min only.
- Continuing in parallel flow configuration and 0.6 ft3/min cold water flow, increase hot water flow to 0.4 ft3/min. Collect temperature data.
- Reverse direction of hot water flow (back to countercurrent flow configuration). Collect data at 0.6 ft3/min cold water flow. Take additional readings at cold water flow rates of 0.8 and 1.0 ft3/min.

Background and Theory:

A single-pass heat exchanger is one through which each fluid runs through the exchanger only once. An additional descriptive term identifies the relative directions of the two streams. Parallel (or co-current) flow is the term for fluids that flow in the same direction. Countercurrent flow describes fluids that flow in opposite directions.

A simple, first law of thermodynamics for each stream gives:

$$q = \dot{m}_c c_{pc} (T_{cb} - T_{ca}) \qquad (1)$$

for the cold fluid, and

$$q = \dot{m}_h c_{ph} (T_{hb} - T_{ha}) \qquad (2)$$

for the hot fluid, where

- q = heat flow, J/s or W
- $\dot{m}$ = mass flow rate, kg/s
- T = temperature, K
- c_p = heat capacity, J/kg-K
- Subscripts c and h denote cold and hot fluids, respectively
- Subscripts a and b denote fluid inlet and outlet, respectively

The following definitions are given for parallel flow:

$$\begin{aligned} \Delta T_1 &= T_{ha} - T_{ca} \\ \Delta T_2 &= T_{hb} - T_{cb} \end{aligned} \qquad (3,4)$$

For countercurrent flow:

$$\begin{aligned} \Delta T_1 &= T_{hb} - T_{ca} \\ \Delta T_2 &= T_{ha} - T_{cb} \end{aligned} \qquad (5,6)$$

The energy transfer between the two fluids is given by:

$$q = UA \frac{\Delta T_2 - \Delta T_1}{\ln\left(\frac{\Delta T_2}{\Delta T_1}\right)} \qquad (7)$$

where

U = overall heat transfer coefficient, W/m^2-K, with subscript *i* or *o*, denoting area used in calculation

A = heat exchange area, m^2, with subscript *i* or *o*, denoting inner or outer heat exchange area, respectively

Pre-Lab Assignment:

1. Write a detailed operating procedure that has:
    a. a sketch of the apparatus, with the valves labeled,
    b. a description of which valves to open and close to set countercurrent flow, and which valves to adjust to change flow rates in countercurrent flow, and
    c. a description of valves to open and close to set parallel flow, and which valves to adjust to flow rates in parallel flow.
2. Sketch the expected temperature profiles for countercurrent and parallel flows.
3. Plan data table layout for lab notebook
4. Do homework assignment given by instructor (instead of pre-lab quiz)

Analysis:

For both countercurrent and parallel flow, do the following:

1. Compare q_c and q_h at each flowrate. Are they the same? If not, how do you calculate U? Also, if not, what errors could contribute to the mismatch?
2. Calculate U for each flowrate and plot U vs. Re of both hot and cold fluid.
3. Calculate the error in U.

Questions to be addressed:

1. Which configuration was more efficient at transferring heat, countercurrent or parallel flow? (Hint: while keeping both flow rates constant, switch the direction of the hot water.) Compare q before and after the switch. Why?
2. How do these results compare with literature?

References:

1. McCabe, Smith and Harriot, *Unit Operations of Chemical Engineering*, Sixth Edition, McGraw-Hill, 2001.
2. Welty, Wicks and Wilson, *Fundamentals of Momentum, Heat and Mass Transfer*, John Wiley and Sons, 1976.