Double Pipe Heat Exchanger

CE 328

Spring 2003

Objective:

To study and evaluate the effects of flow conditions 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. (Valves are red for hot water and blue for cold water.)
- 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. It is adjustable for the purpose of zeroing the reference mark on the tube. 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: Determine the direction of flow to study and the rates of flow that you wish to study. Open or close the appropriate valves. (All globe valves should be totally opened or totally closed.) The metering valves at the outlets should be used to control flow rates. Allow the system to reach steady state before taking measurements. Take at least three readings for each rate, and at least five rates for each flow configuration. *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. (Do not use the same actual flow rates, just change them at the same time.)* Once you have taken readings for all five rates of flow, repeat the experiment for the opposite direction of flow.
- Fix the flow for one of the fluids and vary the other. *(Should you and the group next to you keep the same fluid at a fixed rate?)*

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:

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

for the cold fluid, and

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

for the hot fluid, where

- q = heat, J
- $\dot{m}$ = 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 i and o denote fluid inlet and outlet, respectively

The following definitions are given for parallel flow:

$$\begin{aligned} \Delta T_1 &= T_{hi} - T_{ci} \\ \Delta T_2 &= T_{ho} - T_{co} \end{aligned} \qquad (3,4)$$

For countercurrent flow:

$$\begin{aligned} \Delta T_1 &= T_{ho} - T_{ci} \\ \Delta T_2 &= T_{hi} - T_{co} \end{aligned} \qquad (5,6)$$

The energy transfer between the two fluids is given by:

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

where

U = overall heat transfer coefficient, W/m^2-K

A = heat exchange area, m^2

Pre-Lab Assignment:

1. Agree, with the other team working at the same time as you, which fluid to maintain at a constant rate.
2. Determine five flow rates to be used for each flow configuration of counter-current and parallel flow.
3. Write a detailed operating procedure that has:
   a. a sketch of the apparatus, with the valves labelled,
   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.
4. Sketch the expected temperature profiles for countercurrent and parallel flows.

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.
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?
3. Compare thermometer readings to thermocouple readings, and their effect on the error in U.

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.