**ME 332 Design Project 2**

**Fall 2016**

Due: November XX, 2016 by 12:00 pm to Rogers 334 (no late assignments)

Please slide the assignment under the door, or place on the shelving at the entrance to the room

**Problem:**

As part of your work in a small chemical plant, you have identified a need to quickly cool down a constant supply of a boiling solution being held in a large tank to 30 degrees C. Unfortunately, you do not have a suitable heat exchanger available for use, and your project has a limited budget for purchasing new equipment and operating expenses. Thinking quickly, you decide to create a simple low cost shell-in-tube heat exchanger using commercially available tubing and parts to cool your solution (see figure).

The solution is throttled from the boiler to provide a constant flow rate of 5 liters per minute, and will be gravity fed through the heat exchanger and into another large tank to avoid using expensive pumps. The solution must be brought from 100 degrees C to 30 degrees C in 30 seconds or less to ensure that it is not spoiled. The solution will be at atmospheric pressure while being transferred from tank to tank.

To avoid material compatibility issues (both the solution and the plant make for a corrosive environment), the tubing must be made from Inconel 625 material, which has a current market price of approximately $9.50 / kg. Inconel is hard to work with, so fabrication costs are expected to be approximately 9 times the cost of the raw material (a total cost of $95 / kg).

Wanting to further save cost, you decide that the coolant to be used will be city water, which is maintained at 10 degrees C at the inlet of the heat exchanger. The cooling water will be pressurized to 700 kPa in the heat exchanger. However, the cost of pumping in this water will be approximately $X/liter.

The ambient temperature at the plant is approximately 20 degrees C. The air is stagnant.

**You will need to determine:**

1. An optimal configuration of heat exchanger dimensions designed to minimize cost over 50 hours of operation.
2. The required coolant flow rate to cool the solution in a sufficient amount of time.
3. The temperature distribution along the heat exchanger at every 1/8 of the overall length.

These values will all be recorded in the attached spreadsheet and discussed in your report.

**Assumptions:**

1. Assume that all properties of the solution are similar to water.
2. The material surfaces in the laboratory can be approximated as a gray condition.
3. Assume a steady state condition has been established.
4. You may use either a parallel flow or counterflow design of your heat exchanger. Please specify your selection in the report.
5. Only the heat transfer around the heat exchanger will be considered (no heat transfer through the inlet/outlet pipes or through the tanks).
6. A factor of safety of at least 1.5 should be applied to the thickness of the pipes to prevent damage, however the pipes should not have a wall thickness under 2mm.
7. Inconel 625 has a yield strength of 410 MPa, and a density of 8.44 g/cm^3

**Hints:**

1. In the real world, selection of tube size is often limited by commercial availability, however for the purposes of this project you may assume that the cost of the material is entirely dependent on the cost of the raw material, and that you may order any diameter and thickness you specify without incurring any costs other than material cost and fabrication.
2. A simple hoop stress calculation may be used to find the minimum thickness of the tube walls:

Where *t* is the minimum thickness, *P* is pressure, *c* is corrosion allowance (zero in this case), *S* is allowable (yield) stress, *E* is quality factor (1 in this case), and *Y* is material factor (0.4 in this case).

**Deliverables:**

1. A detailed report.
2. A completed copy of the spreadsheet.

**Report:**

Your report will be graded for being professional and complete. It is to be no longer than 2 pages (not including any appendices). You must convey the approach that you used, and identify any assumptions. Your report must include these sections for full credit: objective, approach (e.g. what equations or correlations did you use), design constraints, assumptions, results, and conclusions. Please include a schematic of your heat exchanger in an appendix.

**Spreadsheet:**

Please attach a completed spreadsheet and any code developed to your report.

**Grading:**

Correct answer: 25%

Correct approach: 45%

Professional report: 30%

**Expectations:**

You are encouraged to work with one partner in completing this assignment. However, you and your partner are to do your work individually (i.e. you cannot copy from other groups). You will submit one set of deliverables.