ME 332 Design Project 2

Fall 2016

Due: December, 2 2016 by 4:30 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 cool a constant supply of a boiling solution being held in a large tank to 30°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 heat exchanger (parallel flow/counterflow) using commercially available tubing and parts to cool your solution (see enclosed figure).

The solution flows from a boiling tank at a constant flow rate of 5 liters per minute, and will be gravity fed through the heat exchanger. 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).

The coolant to be used will be cold air, which is maintained at 0°C and 1 atm at the inlet of the heat exchanger. For safety reasons, the dp/dx of the coolant across the heat exchanger (from inlet to exit) must be approximately 500 kPa/m. The cost of pumping in this cold air will be approximately $0.01/kg. You may assume that the pressure of the cold air is 1 atm. Obviously, this is not physically correct, but this is sufficient for the sake of the project.

You will need to determine:

1. Two optimal configurations of heat exchanger dimensions (one for parallel flow and one for counterflow) designed to minimize cost over 50 hours of operation.
2. All other values specified in the attached spreadsheet.
3. As part of determining the optimal solution, you will need report the values corresponding to inner radius values from 0.5 to 5 cm in increments of 0.5 cm

These values will all be recorded in the attached spreadsheet and discussed in your report. Note that the cost of the material should include both the cost of the inner and outer tubes (which are Inconel).

Assumptions:

1. Assume that all properties of the solution are similar to water at 60°C.
2. Assume a steady state condition has been established.
3. The solution will be flow through the inner portion of the annulus.

4. Only the heat transfer within the heat exchanger will be considered (no heat transfer through the inlet/outlet pipes or through the tanks).
5. The tube wall thickness should be 20% of the outer radius. Additionally, assume that the inner radius of the outer tube is twice the inner radius of the inner tube.
6. Inconel 625 has a density of 8.44 g/cm^3 and a thermal conductivity of 9.8 W/m-K.
7. Assume that the tubes used will be new and that no fouling will exist. The surface roughness is 0.03 mm.

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. The inner diameter of the inner tube and the hydraulic diameter of the outer tube are greater than 1 mm.

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.

In the report be sure to answer this question, “if you could change one aspect of the heat exchanger to reduce the cost, what would it be and why?”

Spreadsheet:

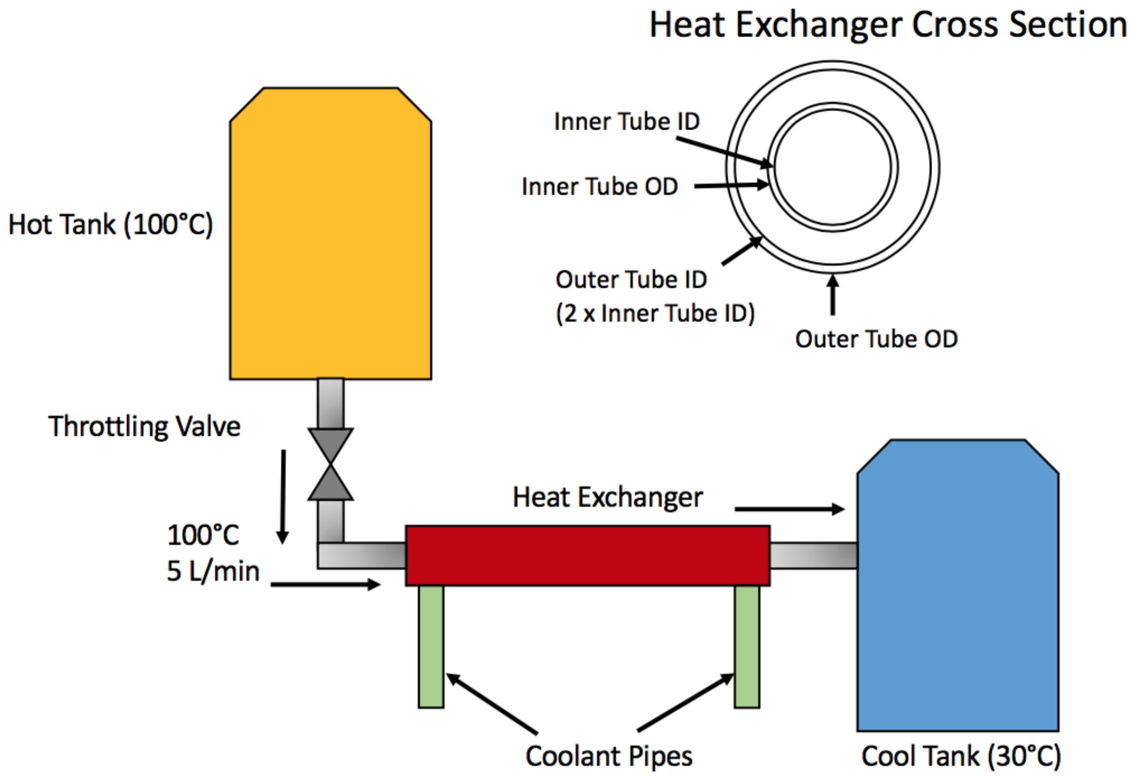
Please attach a completed spreadsheet and any code developed to your report.

Grading:

Correct answer: 20%
Correct approach: 50%
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.


Heat Exchanger Cross Section
Inner Tube ID
Inner Tube OD
Outer Tube ID
(2 x Inner Tube ID)
Outer Tube OD
Hot Tank (100°C)
Throttling Valve
100°C
5 L/min
Heat Exchanger
Coolant Pipes
Cool Tank (30°C)