To: Professor Hecker
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Subject: Proposal to size a heat exchanger

Objectives
Our objective is to collect data that allows us to select a heat exchanger to heat 200 gpm of water from 25°C to 75°C. Our choices are limited to the heat exchangers produced by Standard Xchange (www.standard-xchange.com) Experimental data will be used to obtain sizing parameters. After finding the required surface area, we will select the most economical heat exchanger matching the above criteria. In addition, we will be determining how the flowrate of water impacts the fouling factor.

Introduction
The heat exchanger we will be using is model 03024 SSCF from Standard Xchange with a single tube pass. While there are two exchangers in the lab, we will gather data on unit 1 which has wide baffle spacing. The water running through the tube side of the heat exchanger will be heated by condensing steam on the shell side.

Theory
Heat exchanger efficiency is dependent on a variety of factors. These factors include the fluids involved, their temperatures, and the amount of corrosion/deposition inside the exchanger. Central to heat transfer calculations in heat exchangers is the log mean temperature difference. The formula to calculate this is

$$\Delta T_{lm} = \frac{\Delta T_2 - \Delta T_1}{\ln(\frac{\Delta T_2}{\Delta T_1})} \qquad (1)$$

where ΔT_2 is the difference between the hot and cold streams on one side of the heat exchanger, ΔT_1 is the difference between the hot and cold streams on the other side, and ΔT_{lm} is the log mean temperature difference. This provides an average temperature difference that can be used to provide overall heat transfer properties.
Once we have ΔT_{lm}, we can use an energy balance to determine the heat transfer. A generally used equation to describe heat transfer is

$$Q = UA\Delta T_{lm} = \dot{m}c_p\Delta T \qquad (2)$$

Where U is the overall heat transfer coefficient, A is the heat exchanger surface area in contact with the fluids, Q is the amount of heat transferred, $\dot{m}$ is the mass flow of steam and c_p is the heat of vaporization of steam at the conditions specified.

The overall heat transfer coefficient is defined by the following equation.

$$U = \frac{1}{\Sigma R} \qquad (3)$$

Where each R is a thermal resistance. The thermal resistances involved in this heat exchanger are convective resistance, conductive resistance, and fouling resistance (fouling factor).

$$R_{conv} = \frac{1}{h} \tag{4}$$
$$R_{cond} = \frac{L}{k} \tag{5}$$
$$R_{Foul} = U - R_{conv,c} - R_{cond} - R_{conv,h} \tag{6}$$

where h is the convective heat transfer coefficient and k is the thermal conductivity of the steel of the heat exchanger. As the heat exchanger is well insulated, we will neglect losses to the atmosphere.

Experimental Design

Apparatus

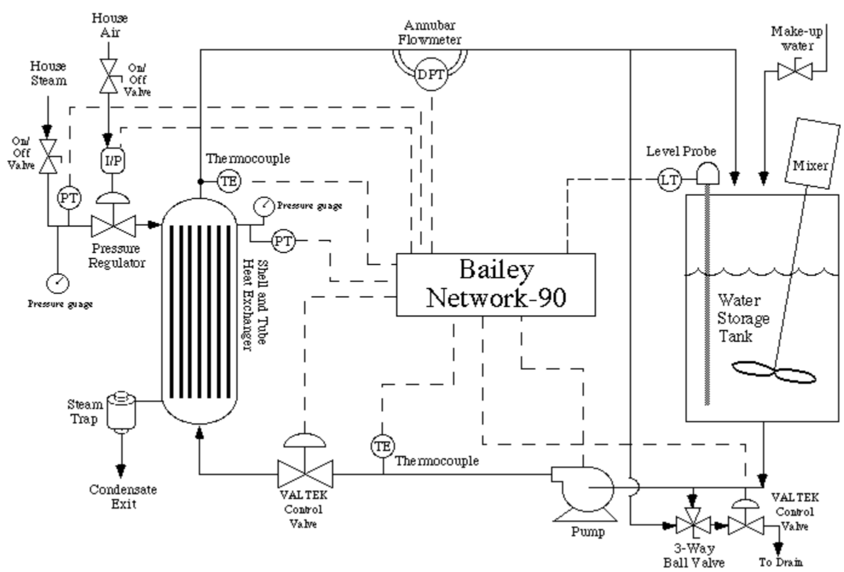

Figure 1: Schematic[1]

Figure 1 shows a schematic of the single-pass heat exchanger system that we will be using. The exchanger has 56 tubes and a surface area of 7.3 square feet. The tubes are 24 inches long while the shell is three inches in diameter. The steam enters through an air-to-open valve which controls the flowrate and thus the amount of heat able to transfer to the tube side. There is a thermocouple monitoring the temperature of the water going into and coming out of the exchanger.

[1] (n.d.). Retrieved October 14, 2014, from http://uolab.groups.et.byu.net/files/shelltube/shelltube_diagram.pdf

Experiment

To determine whether fouling factor and/or the heat duty change with steam pressure, we will run steam through the heat exchanger at four different pressures: 15, 25, 35, and 45 psig. Each pressure will have three trials. In addition, flowrate will be varied to determine whether it has an impact on fouling factor and overall heat transfer. We will measure the water temperature going in and out of the heat exchanger. Assuming that all of the steam condenses and none of the heat is lost to the surroundings, we can calculate how much steam is flowing. The DIPPR database will give us the densities and heat capacities of the fluids. Using this information we will be able to determine the fouling factor and heat duty as outlined in the theory section above.

Expected Outcomes

From the experimental data, we expect to be able to properly size a heat exchanger to heat water at the required 200 gallon per minute flow rate. We also expect to determine the calculated fouling factor and overall heat transfer coefficient. In addition, we expect the fouling factor to not be affected by steam pressure or water flowrate as this should only increase the temperature difference and nothing else.