UNIT OPERATIONS LABORATORY 1

PBL LAB: TUBE-SIDE FLOW THROUGH A SHELL & TUBE HEAT EXCHANGER

ChEn 475 – Knotts

Background

The purpose of this lab is to build one half of a pilot-scale, shell and tube heat exchanger flow system. The size of system you will be constructing, while not large, is used in industries such as pharmaceuticals and biological reagents where technical and/or fundamental limitations allow only small amounts of end product to be made but this end-product is of very high value. Moreover, the principles you will learn constructing this pilot-scale apparatus are applicable to larger versions encountered in high-volume industries.

Another place where pilot-scale systems are used is in training. This can occur at universities, trade schools, or in industrial facilities for initial or ongoing training. There are a few companies that sell "turn-key" shell-and-tube trainers, but they are very expensive and can range in price from tens of thousands to the hundred-thousand-dollar range. You should be able to build your system for much less.

Objectives

Your task is to design, build, and validate a flow system where water is taken from a tank, passes through the *tube-side* of the heat exchanger, and returns to the tank. Your system has to have at least 30 ft of pipe after the pump and achieve flow rates from 1 to 9 gal/min. More explicitly, you should be able to control the system to achieve any flow rate between 1 and 9 gal/min. The design should also incorporate two thermocouples that measure the temperature before and after the heat exchanger so that the performance of the exchanger may be evaluated. The device should also measure the pressure before and after the heat exchanger and the pump. *You want to construct your system to have the smallest capital cost and the lowest utility cost when running.* Finally, another team will be using the same heat exchanger and designing the *shell-side* flow system. Successful completion of this project will require communication and cooperation with this other group.

Multiple pieces of equipment are available for your use as outlined below. You will not (cannot) use all of them and are free to design the system however you see fit to achieve the design conditions given above. But note that part of your grade for this project is based on the quality of the design and your execution. The Pipe Fitting activity, explained below, will help you learn how to build a quality apparatus.

Preparation for Construction

Before beginning any assembly, please deliver a proposal to me outlining your approach. Only one proposal per team is needed. This email should have one or two paragraphs and one or two attached slides that explain your design plan and the rationale (calculations) for your approach. One hint to get you started. You need to evaluate the multiple options you have available, so design a computer tool (Mathcad/Excel/VBA) with flexibility to change inputs. I also want an email update on your progress about half way through the build process. (See the class schedule for the exact due date.)

On the first lab day, after acquainting yourself with the purpose of the lab and the tools you have to accomplish the design goals, you should complete the *Labview Assignment*. Labview is the system you will use to control your apparatus. This assignment will get you started on learning this tool. You may work as a team, but everyone on the team needs to write up a separate assignment to turn in.

Beginning either on the second or third day of the lab, after the Labview assignment, each member of the team will complete the *Pipes, Fittings, and Instrumentation Check-Off Assignment*. The purpose of this is to train you on how to physically construct an apparatus in the proper way. Part of the grade for the PBL lab covers the quality of your design which includes complying with the skills and concepts taught in this training.

Construction and Safety

You may begin constructing your apparatus once you have 1) turned in your proposal, 2) turned in a completed Labview Assignment, 3) turned in a completed *Pipes, Fittings, and Instrumentation Check-Off Assignment*, and 4) receiving approval from the instructor. However, ***before*** powering on or plugging in any part of your apparatus, including the Labview modules, you must explain the safety procedures you have in place to prevent harm to equipment or person including some form of lock-out/tag-out. Again, *make sure your wiring is checked off with either Mike or John before powering on any part of the system.* You will probably do this in stages because you will want to supply power to the Labview modules before powering on the pump. But make sure you fully understand where electrocution can take place for all parts of your system.

Due Date for Apparatus Demonstration and Evaluation

You have until the last PBL lab day to demonstrate that your apparatus fulfills the design requirements. To do this, you will simply show me and a lab manager that it works. At this time, we will also evaluate the quality of your design.

Final Report Requirements

Your final report should give the final results and validation of your project. This is an individual report. It is here that you show the "numbers" that answer the design problem. It should contain a description of the apparatus and quantitatively demonstrate that you achieved the design conditions. It should also address that you did not over specify the system so that the capital and operating costs are minimized.

Logistical and Equipment Considerations

Design Space

Choose one of the two areas, marked by yellow caution tape, near the north wall in the projects lab to build your system.

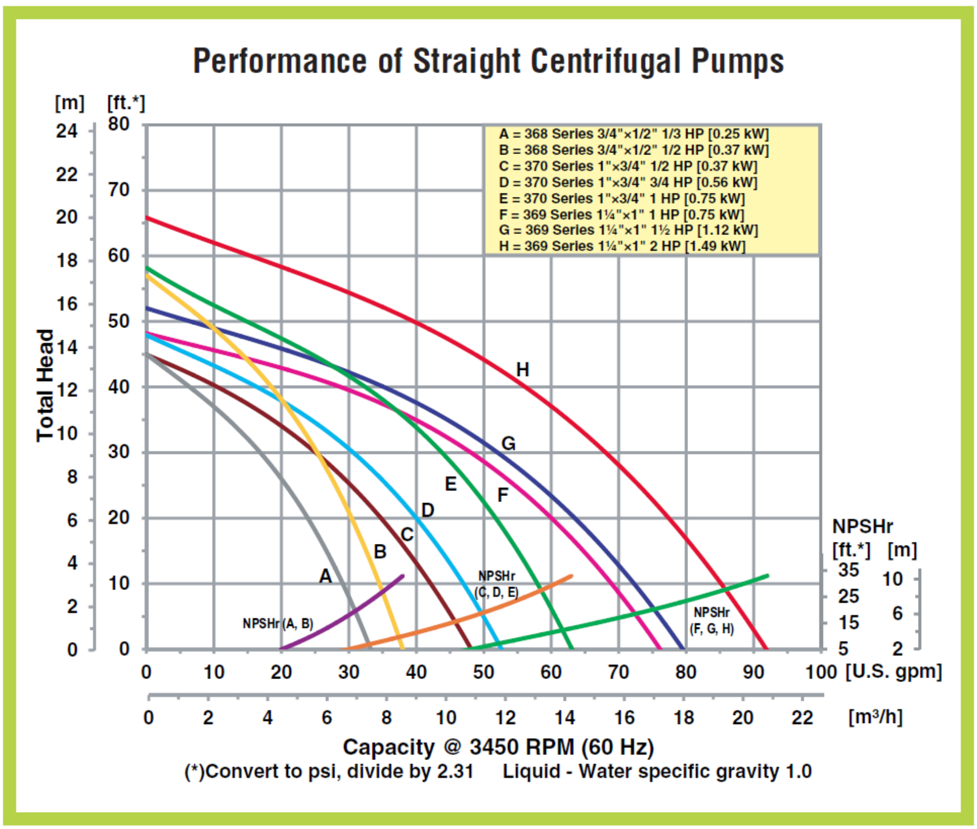
Measurement Options

Two types of devices are available to measure pressures: Bourdon pressure gauges and pressure transducers. The transducers have been obtained from Omega (see website for calibration). Precision turbine flow meters are also available, but these are not the only way to measure flowrate. The pressure transducers and flow meters can be controlled using Labview. These don't have to be used, but are provided if you feel they are needed to achieve your aims.

Regardless of the measurement devices you use, you should be aware of the accuracy of each and factor this into your design and execution (and subsequent grade). Note also that the pressure transducers are expensive and can be destroyed if subjected to a differential pressure that is larger than the stated rating on the device. Also note that stainless steel flanges have been placed around the transducers and flow meters to preserve the threads and reduce replacement costs of these expensive pieces of equipment.

Pump Options

Three different pumps are available: 1/3 hp, 1/2 hp, and 1 hp. The pump performance curves for these is found below. For your convenience, an Excel file named "`PBL Pump Performance Curves and Data.xlsx`" is available on the website (under the hints for the PBL labs) that contains the numerical data from these plots. (Note: stainless steel flanges have been placed on these pieces of "costly" equipment to preserve the threads.)



Pipe and Fittings Options

Schedule 40, galvanized pipe is available in ½", ¾", 1", and 1¼" inch in lengths of 1', 3', and 5'. Jack stands fitted with t-slot are also available so that you can position pipe and equipment in desired locations and arrangements. Various brass and galvanized steel fittings are also available.

Heat Exchanger Information

The heat exchanger is model 02008 SSCF from Standard X-change (http://www.standard-xchange.com/). It has a single-pass tube side and narrow baffles on the shell side. The website has some information on it, but more information, provided by the manufacturer, is available under the hints for the shell and tube heat exchanger lab.

Ideas to Think About and/or Investigate

As you construct your experimental apparatus to answer the design problem, you are going to have to make several decisions. You are also going to answer several questions as you analyze or design the system. These include (but are not limited to) the following:

1. What size of pipe will you use optimize the balance between cost, flow rate, and pump size?
2. What are the boundaries of the system (high/low flow rate, high/low cost, high/low head)?
3. What type of measurements (precision and/or accuracy) will allow you to best report the capabilities of the system?
4. How do you control the flow rate?
5. Do your theoretical design calculations agree with the experiment? Can you explain any anomalies?
6. How will make sure you cooperate with the other team? Where will you place the heat exchanger? Where will you place the tanks?

Deliverables

1. Proposal email (Team)
2. Labview assignment (Individual)
3. Pipe fitting assignment (Individual)
4. Quality of design (Team)
5. Final written report (Individual)
6. Leadership report (Individual)
7. Lab notebook (Team)