Session 1613

DESIGNING A PUMPING SYSTEM: WHY WORRY ABOUT OTHER PROCESS ELEMENTS?

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Abstract

A major goal in integrating design throughout a curriculum is to show students how the major elements of the curriculum fit together. Vertical integration is accomplished by building on concepts learned in previous courses, reinforcing concepts currently being learned, and looking ahead to future material. The process described here is an open-ended design project that is assigned in a junior-level course on fluid flow and heat transfer. In the process, cooling water is pumped from a river, through a condenser on a distillation column, and then to a cooling tower. The students' job is to select the most cost-effective pump and piping for this flow system. This project involves teamwork, decision-making, and the use of spreadsheets, and along the way the students gain a little knowledge about economics. The students also begin to take a broader view of design. Rather than focusing solely on the pump, they realize that the presence of process elements upstream and downstream from the pump can significantly affect their design.

Introduction

One of the best ways for students to learn new material is to have them work on limited, but meaningful, open-ended design projects. To be worthwhile, a project should incorporate several aspects of the lecture material so that students can integrate many of these concepts in an activity. Also, contrary to a capstone design experience, a project should be able to be completed in a week or two so that the students do not get consumed by the project and fall behind in the course (i.e., lecturing is still continuing while they work on their project and the lecturing may be on new material that could be unrelated to the project).

Projects of this type have been used successfully in our department in several courses with the objective of extending the design experience over a major portion of the curriculum. The type of project described here has been used for many years in a junior-level unit operations course, which primarily addresses fluid flow and heat transfer. The process that is evaluated is shown in Figure 1 where a pump is used to convey water from a river, through a heat exchanger, to a cooling tower. The objective is for the students to choose the "best" pumping system for the process based on their engineering calculations and judgment.

Project Example

An example of a typical pump project is provided in this section and the students are given roughly a week to complete the assignment. Most of the information below is taken verbatim from the problem specifications provided to the students. Manufacturers' pump curves are given to the students with this assignment, but, for brevity, those pumps curves are not included here. In this assignment, the analysis of the economics is very crude. The students are informed that they will learn to perform detailed economic analyses in a future course. Also, the costs associated with the pumps and piping were selected somewhat arbitrarily and may not represent actual costs in the field.

"As shown in Figure 1, a mixture of ethanol and water vapors exits the top of the distillation column and passes through a heat exchanger where the vapor is condensed by cooling water. The amount of heat removed from the vapor stream in the condenser is 5.76×10^7 Btu/hr. The temperature increase of the cooling water through the exchanger is 25°F. Cooling water is pumped from a river, through the condenser, and then to a cooling tower that is used to reduce the temperature of the water. Your job is to select the most cost-effective pump and piping for this flow system.

Assume the following:

- process operates at steady state
- globe valve is wide open
- lines drawn at right angles represent standard 90° elbows
- schedule 40 pipe is used (include roughness in the analysis)
- cooling tower operates at atmospheric pressure
- inside diameter of the heat exchanger is 31"
- assume that the condenser contains 500 tubes and that they are 1" BWG 16 and 12-feet long

- <u>estimate</u> the total friction loss due to sudden contractions and sudden expansions in the heat exchanger using the following equation (Bird et al., *Transport Phenomena*, Wiley, New York, 1960, Problem 7I)

$$h_f = \frac{(\text{fluid velocity in a tube})^2}{g}\left[1-2\left(\frac{S_1}{S_2}\right)\right]$$

where S_1 = total cross-sectional area for flow in the tubes
S_2 = cross-sectional area of heat exchanger

Attached are copies of Goulds pump performance curves for you to use in your pump selection. Specify the feasible pumps by manufacturer and by suction pipe size x discharge pipe size - impeller diameter and rotation speed. Base your choice on the following information.

Pump and motor costs (installed): 10 x 12 (1780 rpm) -- $10,000
10 x 12 (1180 rpm) -- $11,000
12 x 14 (1780 rpm) -- $12,000
12 x 14 (1180 rpm) -- $13,000
16 x 18 (1180 rpm) -- $14,000
16 x 18 (885 rpm) -- $15,000

Pipe costs (installed): 10" -- $10/ft
12"-- $12/ft
14" -- $14/ft
16" -- $16/ft
18" -- $18/ft

Operating life: Five years at 8,000 hr/yr

Maintenance costs: 8% of pump/motor cost per year for 1780 rpm
6% of pump/motor cost per year for 1180 rpm
4% of pump/motor cost per year for 885 rpm

Power cost: $0.04/kW·hr

PUT YOUR CALCULATIONS IN A SPREADSHEET SO THAT VARIOUS CASES MAY BE TRIED WITHOUT HAVING TO DO REPETITIVE HAND CALCULATIONS."

These projects are typically done in groups of two or three students depending on the size of the class. Each group is asked to provide results of their analyses in a written report that should include the following sections: summary, introduction, results and discussion, conclusions, recommendations, references, and appendices (showing detailed calculations that support the results). Typically, the assignment is specified to be worth the equivalent of five homework problems, and two-thirds of the report grade is based on the correctness of the technical content and one-third on the quality of the technical writing. To save time for the instructor, the TA for the course grades the detailed technical content, which is usually presented in an appendix, and the instructor evaluates the technical writing.

In order to take full advantage offered by an open-ended design project it is best to ask additional questions about the process. For example, if the temperature of the river water changes, does that affect the pump selection? If the feed to the distillation column increases, how does that affect the design of the pumping system? Would a larger pump be required? Can the heat transfer in the condenser be achieved with 500 tubes? Answering these types of questions requires a higher level of thinking and encourages the students to consider the process as a whole.

Summary

Using open-ended design projects is a very effective approach to aid in student learning. Instead of assigning several back-of-the-chapter homework problems, the project presented in this paper has been used to provide the students with an opportunity to gain a comprehensive view of several concepts in fluid flow (e.g., friction factors, developed head, pump work, equivalent length). The project also provides an opportunity for the students to see how other process elements affect the design of a unit operation.

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Douglas Hirt is an Associate Professor of Chemical Engineering at Clemson University. He received his B.S. and M.S. degrees from Virginia Tech and a Ph.D. from Princeton University. He received the Dow Outstanding New Faculty Award from the Southeast Section of ASEE in 1995, and he has been involved with the SUCCEED Coalition since 1992.

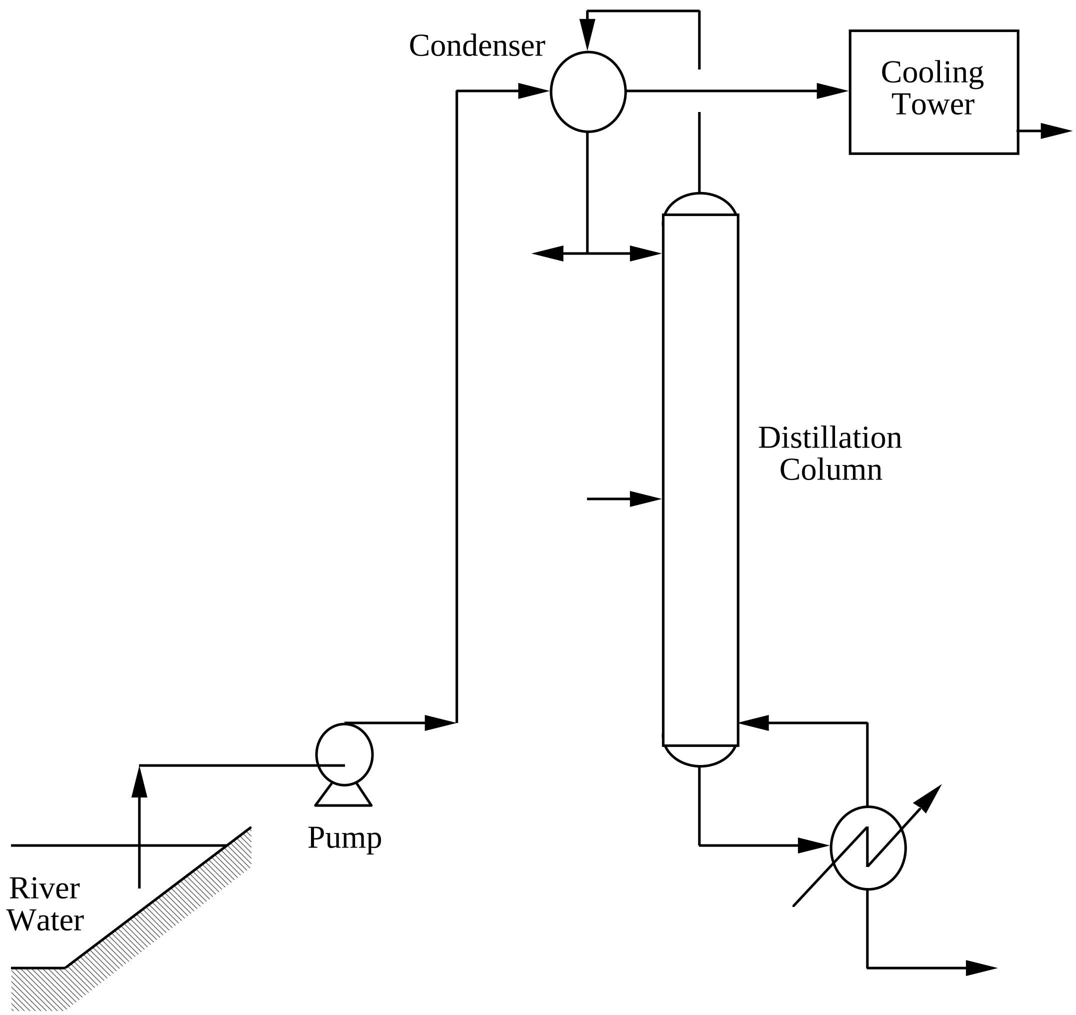

Figure 1. Schematic diagram of one portion of the ethanol case study.