FLOW SHEET IS PROCESS LANGUAGE

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TEXTBOOKS WRITTEN FOR chemical engineering core courses do not generally provide links between the theory presented and industrial practice of process engineering. Many surprises are waiting for students in the plant environment. We have found that this situation can be considerably improved by incorporating flow sheet conception into the lecture program, mainly in unit operations and design courses. The flow sheet forces the student to consider a particular piece of equipment in its true industrial context where it ties in with utilities and basic control strategy. The method not only motivates students to participate creatively, but it also generates questions on process engineering logic that are a welcome enrichment of class activity. This paper will illustrate with examples how students can be induced to ask these questions and to find answers to them.

FIRST HEAT EXCHANGER EXAMPLE

To illustrate the calculations for heat transfer to jacketed tank reactors, we went through an example solved in a well-known textbook [1]. Knowing the heat

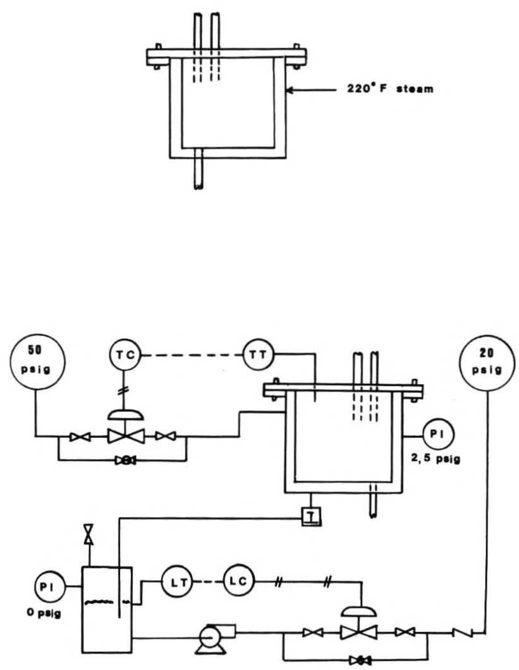
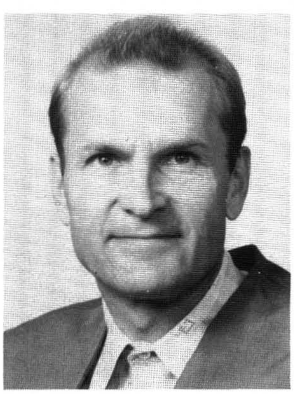


FIGURE 1. Steam supply to reactor jacket. Above: book approach. Below: flow sheet approach.

load and the available surface, the steam temperature required in the jacket is found to be 220°F. The subject matter of the book goes this far, but thinking that this was not a real challenge to my students, I went on to speak some process language: our plant has two steam headers, 50 psig and 150 psig, and a condensate return header at 20 psig. I asked the students to prepare a flow sheet with enough details to show exactly how steam flows from which of the supply headers through the jacket and back into the return header. The jacketed reactor then acquires its true identity as part of the processing unit. This is process language. Some quite common "nonsense situations" were submitted from which a lot could be learned about the logic of process engineering. Can you imagine a pump at the jacket exit that simply pulls the steam through from the supply header? Figure 1 shows a workable solution. It also depicts the difference between a book approach and a flow sheet approach to the problem.



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SECOND HEAT EXCHANGER EXAMPLE

When studying the thermal design of shell and tube exchangers, we went through an example solved in another well-known textbook [2] which states that "atmospheric pressure steam condenses on the shell side." Nobody objected to this as long as we were busy figuring the number of tubes and passes. The surprise came when I again asked for the flow sheet. Only then did it become clear that book language is not process language. Even the simplest steam trap requires a pressure drop to function, which means that in addition to the equipment shown in Figure 1, it will be necessary to pull a vacuum on the condensate collection tank in order to make the steam flow at all. What is more, this vacuum has to be monitored if a pressure of 1.00 atm. abs. is to prevail in the shell. The flow sheet question helped integrate the exchanger into the processing environment, and it became evident that atmospheric pressure was a poor choice for the shell.

EVAPORATOR EXAMPLE

The typical textbook evaporator calculation [3] will state the presure in the last effect to have a certain value, such as 100 mm Hg absolute or 26 in Hg vacuum. All calculations are based on this number, although no effort is made to explain its source. In addition, our school is located 3500 feet above sea level where 26 in Hg is considered perfect vacuum. This is another excellent situation to be explored with process language. I got surprised looks when I asked, "Would you please supply a flow sheet?" and, "What would you do if some day you were asked to operate at 23 in Hg vacuum?" The problem statement in the book did not require that the student think this far ahead. Many misconceptions about vacuum equipment can be dispelled by simple confrontation of sense and nonsense on the flow sheet. Can you imagine a pump that sucks out all the vapor produced in the last effect? The surprised looks disappeared as the answers slowly took shape. A workable solution is presented in Figure 2. Again, the figure compares book approach to flow sheet approach to show the enrichment obtained through process language.

DISTILLATION PRESSURE EXAMPLE

An uncommon situation appeared in the study of the conversion of fermented beer into 96 volume % ethanol in two distillation towers. The equilibrium conditions are such that no reflux is required in the first column. The overhead vapor containing 24 mol % ethanol is fed directly to the appropriate plate of the second column. On paper, the two columns looked like any column depicted in textbooks, with the number of plates determined by the method of McCabe-Thiele and the feed plates chosen accordingly. Mass and heat balances closed with the correct amount of open steam at the bottoms and the correct amount of cooling water in the second column condenser. There was but one little problem: At the start, on deciding the operating pressure, there was no reason for it to be much different from atmospheric. A distilling company was consulted and the information obtained that the first column runs at 3 psig, which confirmed our reasoning. Consequently, the design proceeded with this pressure. When the time came to provide a flow sheet, there was no variable available for manipulation to control the first column pressure. Textbooks were consulted but no answer was found. On combining the flow sheets of the two towers and after a brainstorming session, the fact slowly emerged that the first column pressure in this scheme is not an inde-

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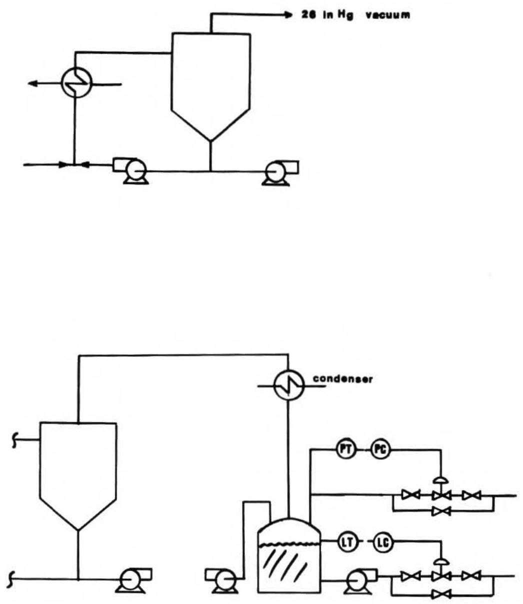

FIGURE 2. Condensate collection from evaporator. Above: book approach. Below: flow sheet approach.

pendent variable as it is in standard reflux columns discussed in the books. The second column pressure has to be controlled at the condensate drum, and the first column pressure would then find its own equilibrium value, much like it does in a double effect evaporator. Had the problem been terminated at the textbook stage, this "discovery" would have been lost.

CONCLUSIONS

Flow sheet is process language. Process language is exciting. Process language transforms book examples into process plant examples. Process language resorts to the use of utilities to vitalize unit operations teaching. Process language is a stimulating teaching tool.

LITERATURE CITED

1. Kern, D. Q., *Process Heat Transfer*, McGraw-Hill (1950). Example 20.1
2. Foust *et al.*, *Principles of Unit Operations*, 2nd Edition, John Wiley & Sons (1980). Example 15.1
3. McCabe, W. L., J. C. Smith, P. Harriott, *Unit Operations of Chemical Engineering*, 4th Edition, McGraw-Hill (1985). Example 16.1

ChE book reviews

DISTILLATION TRAY FUNDAMENTALS
by M. J. Lockett
Cambridge University Press, Cambridge and New York, 1986. 224 + xxiii pp. $54.50

Reviewed by
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The distillation column continues to be the principal separation device for the chemical and petroleum processing industries. For many years it was characterized as a vertical, cylindrical column containing plates or trays upon which rising vapor and descending liquid were brought into intimate contact, for purposes of effective mass transfer. In recent years designers of distillation columns have shifted some attention to the use of structured (as opposed to random) packings as vehicles for effecting intimate phase contacting. However, such packings are considerably more expensive than trays, and their cost is often justified only when their lower pressure drop carries an economic advantage, as in some vacuum distillations. Thus, the tray column remains as the standard and basic device for vapor-liquid contacting.

Despite the title, this book deals not only with trays for distillation services but also covers applications in absorption and stripping. It covers all of the important aspects of tray design, those of a more hydrodynamic nature as well as those relating directly to the mass transfer propensity of the two-phase mixture on the tray. Considerable space is devoted to the characterization of this mixture: foam, emulsion, froth, spray, and so on. The overall coverage is quite complete, with no detail of design left unaddressed. Such important topics as phase flow distribution, capacity limits, pressure drop and interphase mass transport are dealt with on quantitative bases. A commendable effort has been made by the author to consider all historical approaches (mostly empirical) that deal with the various design parameters. The literature coverage is near exhaustive, and the reader will not find elsewhere as complete a bibliography on the distillation tray as is provided here. For each design consideration, a method with some fundamental and mechanistic support is provided—and for practitioners of distillation system design this is a welcome advance from the art and empiricism that have often prevailed.

There are some limitations to the treatment that should be mentioned. First, the author has not always found it possible to make a forthright recommendation when several alternate models or procedures are available for a particular design step. The reader must then make his own choice. Also, despite the title, all tray-type contacting devices are not considered. There is very little on valve trays, essentially nothing on bubble-cap trays, and complete silence on dualflow trays (those without downcomers). Emphasis is clearly on crossflow sieve trays, but this is not all bad. While there are still many bubble-cap tray columns in operation, very few new ones have been designed during the last few decades. The valve-tray is really a proprietary contactor, with design often left up to the proprietor. The dualflow tray is a rather specialized device (and tricky to design), used mostly for fouling services. On the other hand, the sieve tray is an efficient and relatively inexpensive non-proprietary device that has been the object of many basic studies, and its simple geometry (in effect, one or more sheets of perforated metal, joined to a downcomer for handling liquid passage) makes it reasonably amenable to fundamental modeling. Still, the title might have read "Distillation *Sieve* Tray Fundamentals."

The book might have been improved by the inclusion of some worked-out design examples, some advice on laboratory or pilot plant scaleup procedures, and an author index. Still, the development of rational, fundamental-based approaches to the handling