

COMPLEMENT TO DESIGN:

Trouble-shooting Problems

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Ideally, every final year engineering student should be given a course that coordinates all he has learned and shows him how to apply his knowledge in industry. Such a course should illustrate economics, require both creative and analytical thinking, give practice in asking the right questions, and instill some practical know-how.

Traditionally a design project has been used to satisfy these requirements. There is, however, another teaching method that can satisfy them: trouble-shooting problems. Trouble-shooting problems have been enthusiastically received by the chemical engineering students for the past couple of years as a complement to design projects at McMaster University. This paper discusses the adaptation of trouble-shooting problems to class use. Several examples are given.

What are Trouble-Shooting Problems?

Trouble-shooting problems are typical plant situations in which a section of the plant is not working right. A straight-forward solution cannot be reached on the diagnostics available; some experimentation is usually required to isolate and correct the difficulty. The objective is to get the plant running properly with the minimum total cost.

The problems are solved much as a detective solves a murder mystery. A detective may search for additional clues or he can make an arrest immediately. By searching for further clues first, he has more proof that he is arresting the real culprit. Nevertheless, the more time he spends searching for clues and pursuing red herrings before making his arrest, the lower his rating as a detective. Similarly, the student may try to correct the plant trouble from insufficient evidence or he can perform experiments and ask questions to pinpoint the trouble. The more money (*time, labor and equipment*) he spends before he gets the plant going again, the lower his rating as an engineer.

Adaptation to Class Use

At McMaster the trouble-shooting problems were worked in class, and the following general philosophy was adapted. The students worked individually and each at his own pace. They obtained information by requesting it from blueprints and from plant history, or by performing experiments. Either way, they purchased information because they were charged for any downtime, loss of production, labor, or equipment needed for each request.

The Procedure Adopted Was:

1. All that the students knew about the plant was given on the problem sheet. No background experience was expected. Other information (*such as flow diagrams, mass balances, and operating data*) were available, at a price, for the asking.
2. More than one thing could have been wrong on the plant.
3. Use of any textbooks, especially cost estimating notes, was encouraged.
4. Each student worked on his own.
5. A problem was complete when the plant was working correctly, and the student had estimated the total cost incurred correcting the trouble.
6. The student was told to assume that there was negligible error above and beyond the instrument limitations for any laboratory or experimental work done.
7. The purchase of information was irreversible. Once an experiment had been run and the results given, the money spent to obtain the information was charged against the student's account and could not be recovered whether he actually used the information or not.
8. The mechanism for purchasing information was as follows:
 - (a) The student specified in *detail* in the left hand column of the worksheet (shown in Exhibit B) exactly what he wanted done. An instruction like "*measure the temperature*" was unacceptable. The student had to

EXHIBIT A -- TROUBLE-SHOOTING PROBLEM 1

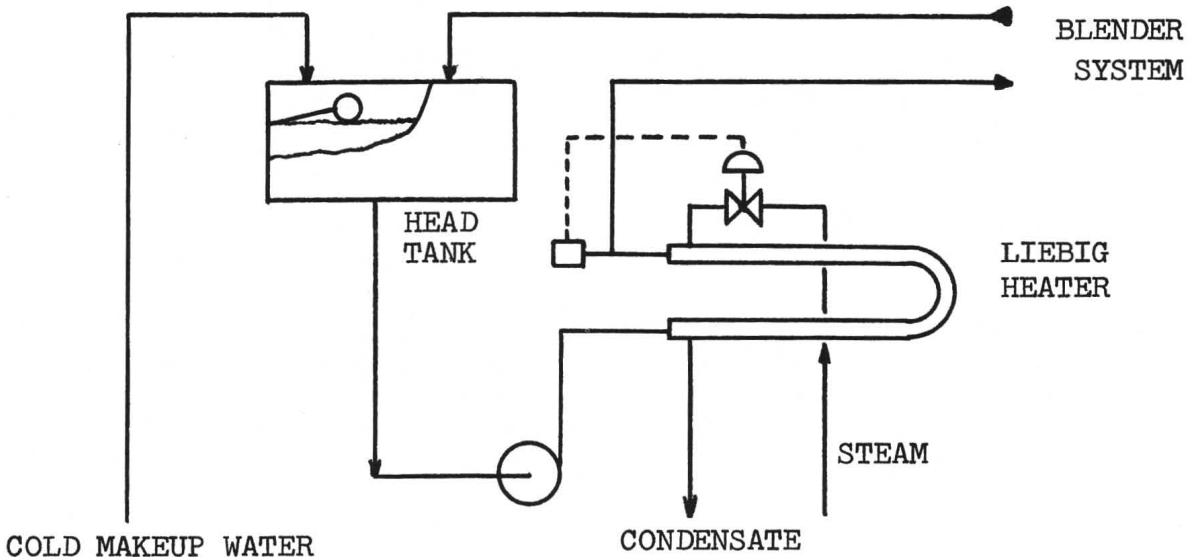
Stearine Blender

The quality of blended stearine depends upon the temperature; stearine discolors if it is kept at too high a temperature too long. Furthermore, the stearine is kept at 2 to 3°C above its freezing point to minimize the setting or solidification time. The next stage after the blender is blocking and flaking.

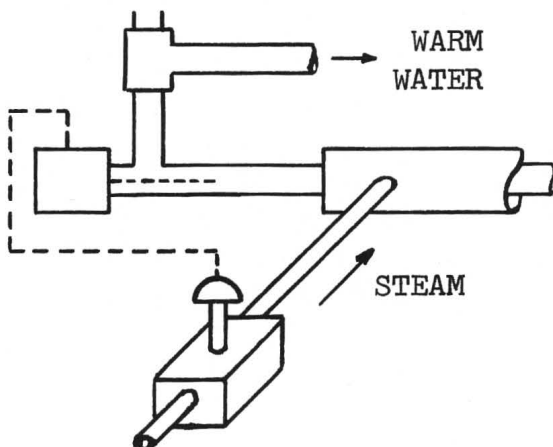
To satisfy the above requirements, warm water (65°C) is circulated

1. in the jacket around the blend tank;
2. through jackets around all stearine lines;
3. through coils in the blend tank.

A simplified sketch of the warm water circuit is shown below.



DETAIL OF HEATER EXIT



Problem:

For the past 12 hours the stearine has been off-color and has required a longer time to solidify than usual. The blender handles 20 tons/24 hours. Specification-grade stearine is worth 16¢/lb. The boss comes into your office and exclaims: "Get this plant going correctly!"

specify the instrument to be used, and its location. The details had to be sufficient so that a non-engineer could perform the task.

(b) The student estimated the cost of the experiment or request and reported this in the central column. This included downtime, loss of production, his time, cost of equipment and labor.

(c) He indicated to the instructor that he wished to purchase the answer to the proposal described in (a) for price (b). The instructor commented on the cost estimate, adjusted it if necessary, and then supplied an answer in the right hand column of the worksheet. The answer was for the experiment described. If the instructions were incomplete, a \$50 penalty was imposed, and the student rewrote the instructions.

9. This procedure for purchasing information was repeated until the instructor indicated that the trouble had been corrected. The costs were totalled, the worksheets handed in and the next problem tackled.

10. The marking scheme was as follows: Five marks were given for completing each problem; to this was added a mark out of five that was prorated by relating the student's cost to the minimum cost. A 50% allowance was made to the minimum cost because of the student's lack of experience and because of the impossibility of his visiting the physical plant. Thus, the student's mark was evaluated by the following relationship

$$\text{Mark} = 5 + 5 \left(\frac{\text{Minimum Cost} \times 1.5}{\text{Student's Cost}} \right)$$

Examples and Comments

A problem is given in Exhibit A. To illustrate the procedure, a student's approach to solving this problem by the prescribed method is given in Exhibit B. This is a good problem with which to start the series because it is simple, and because it helps the students to realize early in these problems that instruments cannot always be trusted. Additional problems are given in Exhibits C, D, and E.

These problems were worked in class. They are not adaptable as homework assignments because of the required-question immediate-answer approach

Exhibit B Student's Worksheet for Problem I Plant Trouble-Shooting

Problem Number 1 Name: J. MacDonald
Date March 16 Time Taken 30 minutes

<u>PROPOSAL</u>	<u>COST</u>	<u>RESULT</u>
Find temperature of return water with a thermometer	\$65	Incomplete Instruction
	\$50	Penalty
Study the plant blueprints to see if there are valves on line to and from blender	\$35	No valves in line from heater to head tank
Is there a manual control on the controller?		No manual control on controller
Measure the temperature of water from the Blender Jacket by immersing a thermometer in the open discharge of the water into the head tank. Use a 200 degree C. thermometer.	\$65	72 degrees C.
Remove the plug in the tee in the line after the heater (as shown in detail).	\$65	Insufficient time
Insert a rubber stopper through which passes a thermometer	\$25	Penalty
		Hot water over everybody (because you didn't shut off the pump first)
Reset control temperature so that exit water temperature (as read on thermometer) is 65C.	\$120	The problem has been solved but what about the man holding the rubber stopper?
When is the next shutdown?	\$ 5	4 days
Stop pump. Remove stopper and thermometer, replace plug, put a "Do Not Touch" sign on the controller. Check with instrument department to have a new recorder-controller ready for shutdown. Issue work order for the replacement of instrument during next shutdown. Repair old controller.	\$65	Satisfactory
	\$50	
	\$610	

$$\text{Mark} = 5 + 5 \left(\frac{1.5 (370)}{\$610} \right)$$

$$\text{Mark} = 9-1/2$$

and because the problems are so open-ended that a computer program would be too complicated. One instructor and a graduate assistant handled ten students with negligible delay.

The first problems to be tackled illustrate these points: instrument calibrations should be checked; flow diagrams are not always up-to-date, and plant operators can accurately describe symptoms but their diagnosis of the trouble may be wrong. It took an average of 35 minutes to do each problem. Although the problems cited have described chemical processes this approach should be easily adaptable to other engineering situation.

It is interesting to note that some of the students who did very well with this type of problem were those who had a low mark on other courses and on other types of problems.

Summary

Trouble-shooting problems are enthusiastically received by chemical engineering seniors as a complement to

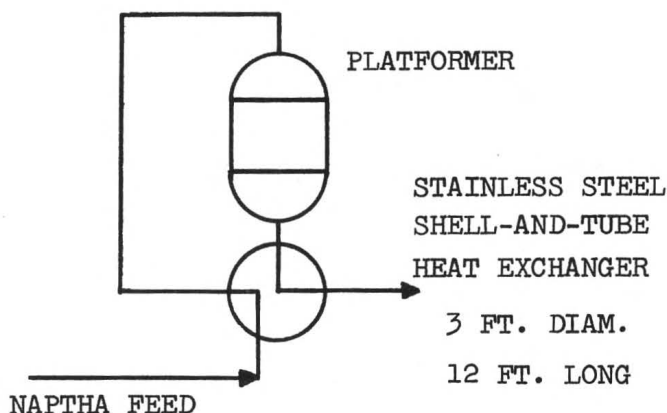
design problems. These trouble-shooting problems offer a good method of illustrating economics, providing creative and analytical thinking, instilling practical know-how, co-ordinating previous course work, and illustrating another aspect of engineering responsibility. A successful method of class adaptation has been presented, along with details of students' operating rules and a worked example. Although the two years of experience reported has been in chemical engineering, this powerful teaching technique can easily be adapted to other disciplines.



EXHIBIT C -- TROUBLE-SHOOTING PROBLEM 2 Platformer Fires

Background:

Heavy naphthas are converted into high-octane gasoline in "Platforming." Byproducts of the reaction include low-pressure gas and hydrogen-rich gas containing 60 to 80% hydrogen. The products from the platformer reactor (at 700 psig and 500°C) are heat-exchanged with the feed naphtha to preheat the reactor feed.



Problem:

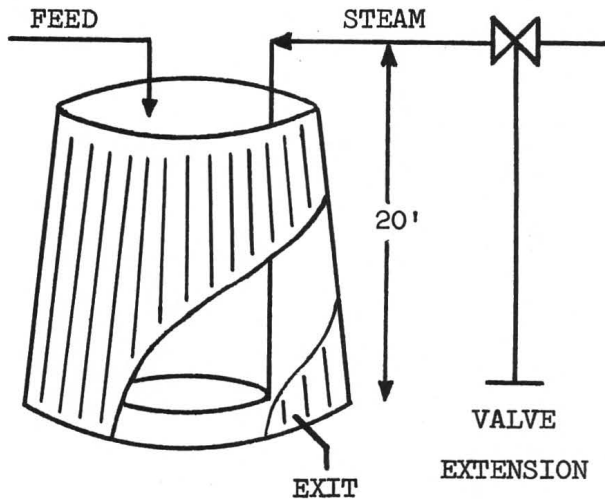
"In the three weeks since startup, we have had four flash fires along the flanges of the heat exchanger. The plant manager claims that because of the differential expansion within the heat exchanger, because of the diameter of the exchanger and because it's hydrogen, we're bound to have these flash fires. The board of directors and the factory manager, however, refuse to risk losing the \$9 million plant. Although

the loss in downtime is \$5000/hr., they will not let the plant run under this flash-fire hazard condition! Fix it!" says the technical manager.

The maintenance men have already broken 6 bolts trying to get the flange tighter, but they just can't get it tight enough.

EXHIBIT D -- TROUBLE-SHOOTING PROBLEM 3

Fat Splitting in a Twitchell Tub



Grease or fat can be converted to fatty acids and glycerine by a number of processes. An out-of-date process -- yet one that still handles some material in your plant -- is the Twitchell process. In this process, water, grease, Twitchell's reagent and sulfuric acid are boiled for about 10 hours in a 25-ton-capacity wooden vat. Live steam supplies the heat and the mixing. The steam line goes to the base of the vat, and then makes a loop around the bottom. This 2-in. diameter pipe has 1/4-in. holes in the side of the pipe that forms the loop.

An operator runs into your office and says: "I've just filled number 1 Twitchell tub with charge and turned on the steam. But nothing happens!"

The company loses \$100 every hour this tub is out of operation.

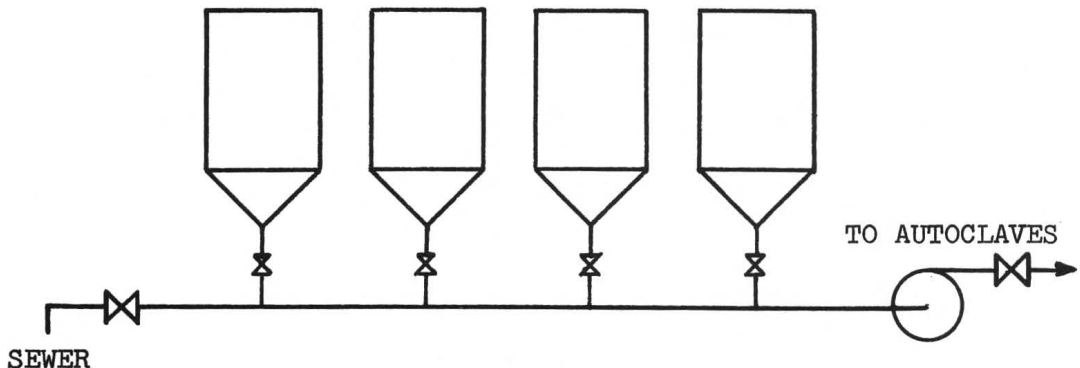
EXHIBIT E -- TROUBLE-SHOOTING PROBLEM 4

Crude Grease Cleansing

Grease must be cleansed before it can be sent to mild steel autoclaves for conversion into fatty acids. This consists of treating the grease with a sulfuric-acid water mixture in a cyclic process involving the following operations:

1. Boil
2. Settle
3. Run off acid-water
4. Add pure water and mix-settle to wash the fat free of sulfuric acid
5. Drain off wash water and send fat to autoclaves.

Recently, the old cleansing system was replaced by four lead-lined 25-ton-capacity tanks arranged as sketched below.



We observed pitting and corrosion in the autoclaves about two weeks after the new tanks were installed. The product is worth 15¢/lb. Remedy the situation. This system handles 30 tons/hr.