BURNET.

CHEMICAL ENGINEERING EDUCATION

JANUARY 1966

COMPLEMENT TO DESIGN:
Trouble-shooting Problems

The Prentice-Hall International Series in the Physical and Chemical Engineering Sciences

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CHEMICAL ENGINEERING EDUCATION

Contents for Volume 1, No. 2, Jan. 66

EDITORS' CORNER

Strong has been the sound and great the fury generated throughout the land by the Preliminary Report of the ASEE Goals Committee. And the end is not yet in sight. Chemical engineers, academic and industrial, were among the first to speak up, and they continue to contribute substantially to the din and frenzy. Thus far the clearest and the most numerous voices have the accent of con, and this is to be expected. After all, the Report itself presents directly and, indeed, in semi-official tones the pro view, and there is really little incentive for those who agree to join the voice that rumbles, as it were, from Sinai.

For the moment **CHEM ENG ED** takes no position in the Goals controversy. To do so now would be premature and improper.* But this we can assert: the fierce outcry and the Report that induced it certainly do not signify nothing! The fact of the Report, the fact of the subject matter, the fact of the authoring Committee are tremendously significant. Even more so is the immediate and spirited if disputatious response. Most significant is the thread of consonance in that response, arising as it does spontaneously from many scattered nuclei. Clearly engineers care about the goals of engineering education and care enough to try to implement their convictions. What could be healthier? When the dust has settled and the quiet of resolution is restored, the race will have inched itself another notch in the direction of better professional education.

* A sub-committee appointed by the Executive Committee of the Chemical Engineering Division is studying the Report and will present a statement to the Division at the June meeting of the Society.

CHEMICAL ENGINEERING EDUCATION

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CED /AIChE **NEWS**

Divisional activities are a great part of the strength of the American Society for Engineering Education. Without its divisional sessions, the annual meeting of the Society would be of less significance. The Chemical Engineering Division takes great pride in the programs it has arranged for past meetings, and equal pride in presenting the one planned for the 74th Annual Meeting of ASEE, to be held at Washington State University, Pullman, Washington, June 20-24, 1966. It is outlined below. The Executive Committee of the Chemical Engineering Division urges all who are interested in chemical engineering education to come to Pullman and attend all of the sessions.

Preliminary Program
Chemical Engineering Division
American Society for Engineering Education

ANNUAL MEETING
Pullman, Washington

June 20–24, 1966

Division Sessions

Tuesday, June 21, 1966

8—9:45 P.M.

Executive Committee Meeting
Presiding: J. B. West, Oklahoma State Univ.

10—11:45 A.M. 2—3:45 P.M.

CH. E. WORKSHOP
Improved Approaches to Solution of Ordinary and Partial Differential Equations by Use of Numerical Analysis and High-Speed Digital Computer.
Presiding: J. O. Wilkes, University of Michigan

Wednesday, June 22, 1966

10—11:45 A.M.

NEW APPROACHES
in the Teaching of Undergraduate Courses in the Chemical Engineering Curriculum.

Presiding: W. H. Corcoran, California Institute of Technology.

1. A Junior Course on Matter, Energy and Forces.
   C. Michael Mohr, Massachusetts Institute of Technology.
2. Introduction of Chemical Engineering to Freshman Students.
   R. L. Pigford, University of Delaware.

12—1:45 P.M.

Chemical Engineering Division
BUSINESS LUNCHEON
Presiding: J. B. West, Oklahoma State Univ.

6 P.M.

Chemical Engineering Division
ANNUAL BANQUET
Presiding: J. B. West, Oklahoma State Univ.
Technology.
Speaker: W. W. Churchill, Univ. of Michigan

Thursday, June 23, 1966

10—11:45 A.M.

Chemical Engineering Division
ANNUAL LECTURE
Presiding: J. B. West, Oklahoma State Univ.
Speaker: Octave Levenspiel, Illinois Institute of Technology.
"Changing Attitudes to Reactor Design"

2—3:45 P.M.

PANEL DISCUSSION

on the Relation between Biomedical Engineering and Teaching Chemical Engineering.
Presiding: E. L. Gaden, Jr., Columbia Univ.
Panelists:

1. R. L. Bell, University of California, Davis, California
2. Giles Cokelet, California Institute of Technology.
3. K. E. Keller, University of Minnesota.
4. R. E. Sparks, Case Institute of Technology
5. Robert Weaver, Tulane University

COMPLEMENT TO DESIGN:

Trouble-shooting Problems

Donald R. Woods
Assistant Professor of Chemical Engineering
McMaster University, Hamilton, Ontario, Canada

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 completement 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

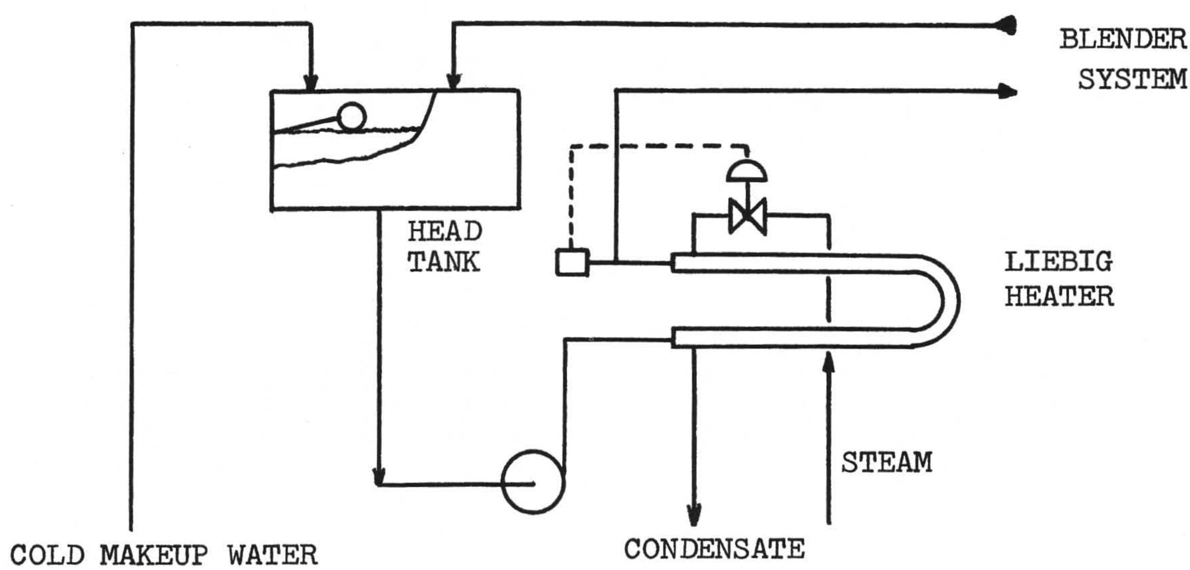
Stearine Blender

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.

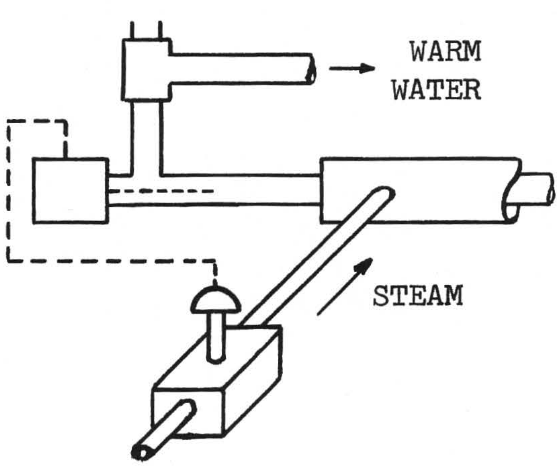
To satisfy the above requirements, warm water (65°C) is circulated

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 sufficent 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

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

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

PROPOSAL	COST	RESULT
Find temperature of return water with a thermometer	$65 $50	Incomplete Instruction 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 conrol 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). Insert a rubber stopper through which passes a thermometer	$65 $65 $25	 Insufficient time Penalty Hot water over everybody (because you didn't shut off the pump first)
Reset control temperature to about 45 degrees C. 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 $50	Satisfactory
	$610	

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

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

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

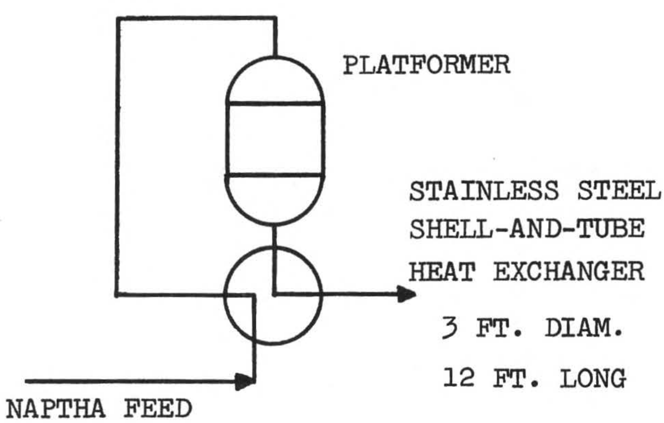
Trouble-shooting problems are enthusiastically received by chemical engineering seniors as a complement to design problems. These trouble-shooting problems offer a good method of illustrating economics, providing creative and analytical thinking, instilling practical know-how, co-ordinating previous 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 napthas 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 naptha to preheat the reactor feed.



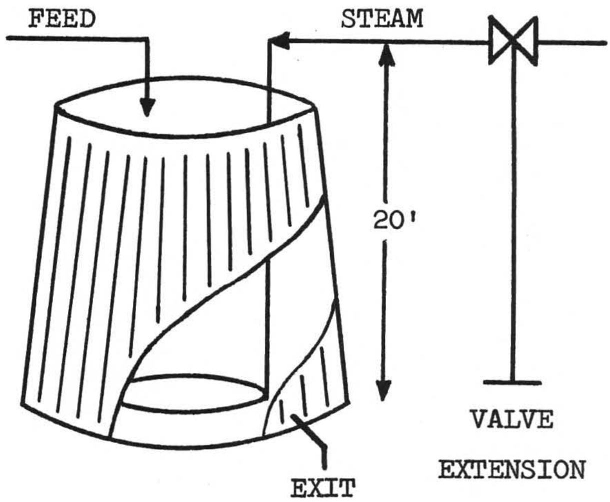
Problem:

"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 manger, 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.

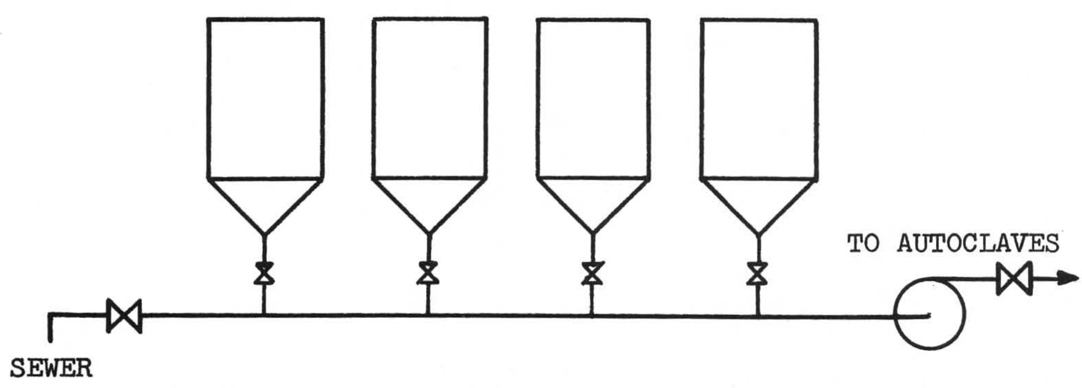
EXHIBIT E -- TROUBLE-SHOOTING PROBLEM 4

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.

A New Chemical Engineering Option in an Engineering-Science-Oriented Core Curriculum

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This paper describes a new chemical engineering option for students within a radically different engineering-science-oriented core curriculum. For orientation purposes, before discussing the chemical engineering option, it will be necessary first to describe briefly our new engineering program, now in its third year of operation. Pennsylvania Military College, a small college of 1200 day students, of which 200 are engineering students, had previously no traditional chemical engineering discipline. In September, 1962, P.M.C. started on a completely new approach to undergraduate engineering education with eight new faculty including a new Director of Engineering. The program is founded on the principles that there is a set of basic subject matter that is common to all engineering disciplines, that a B.S. degree in engineering is really only a pre-engineering degree, and that graduate work is essential. Thus, the P.M.C. engineering faculty has initiated a new curriculum taken by all engineers, with heavy enphasis on mathematics and the physical and engineering sciences, for three of the four year required for the B.S. in Engineering degree **(undesignated)**. The senior student takes recommended courses in a specialty such as chemical, electrical, mechanical, or civil engineering with crossing of disciplines to suit the student's interest, under the guidance of an engineering faculty advisor. Two courses in the senior year are common also: Energetics, which includes direct energy conversion, and Senior Projects, a creative engineering activity (a complete curriculum is presented in the Appendix). Almost all engineering courses within the core program are lectures; the laboratory sequence, starting in the sophomore year, is run as an internship in engineering through interdisciplinary projects. Within the three years of core program, traditional chemical engineering does have a strong emphasis, as will be described. The fourth year option in chemical engineering is broader than traditional as a result of the unique interdisciplinary emphasis and heavy math and science preparation.

The emphasis on a mathematical approach to engineering is pronounced throughout the program. Immediately in the freshman year, the students program and use an IBM 1620 digital computer. The purpose of the computer course this early is to orient the student toward the modern engineering attitude and to develop a professional method of problem solving. In most core engineering courses, several faculty are involved in teaching, and a definite attempt is made to have these teachers from various traditional backgrounds.

The sequence of four courses given by the Mathematics Department starts with calculus and vectors the freshman year and uses a text similar to Agnew's **Calculus: Analytical Geometry and Calculus, with Vectors**, McGraw-Hill, 1962). The fourth semester of mathematics is probability and differential equations. A separate course in differential equations or advanced mathematics is not included in the curriculum, since all engineering courses develop the necessary mathematics for dealing with dynamic situations and advanced topics. The four physics courses, the first of which starts at the beginning of the freshman year, have used the text by Halliday and Resnick (John Wiley, 1963). The fourth semester of physics is what is usually termed modern physics and is an introduction to quantum mechanics and solid-state physics.

In the second sophomore semester and first junior semester, a strong new course in engineering, Systems Dynamics, is required. Developed by our director of engineering while at MIT, the course relates fluid, thermal, mechanical translational, mechanical rotational, and electrical systems by recognizing underlying mathematical analogies of the through and across variables in the governing dynamic laws. That is, fluid flow and pressure drop are related to current and voltage such that the dynamic equations for fluid capacitance, inertance, and resistance can be related to electrical capacitance, inductance, and resistance. Likewise, current and voltage are related to force and velocity such that the governing dynamic laws for electrical capacitance, inductance, and resistance are shown to be analogous to those governing a mass, spring, and damper. Then, by use of linear graph and network theory, complicated systems are reduced to a mathematical model representative of the dynamic situation. Extensive use is made of the analog computer. Before the end of their sophomore year, students have been able to write and program the kinetic equations for a first-order consecutive reaction, $A \rightarrow B \rightarrow C$. First-semester juniors have simulated a stirred tank batch reactor varying both the heat and flow inputs. In addition to exposure to these typical chemical engineering problems, all engineering students also have had such experiences as deriving the dynamic equations for an automobile suspension system and simulating this on the analog computor. Under an open-shop policy, over $70,000 worth of new analog computers and read-out and display equipment is used by students in this course. It should be noted that students finishing the course have worked with Fourier analysis and Laplace transform and have been introduced to stability considerations. As a result, the senior year course in Chemical Process Dynamics and Control starts at a level commensurable with an initial graduate course in more traditional departments.

The junior year has two courses weighted to a traditional chemical engineering program. One, Flow and Fields, has been taught collectively by two professors with chemical engineering and electrical engineering backgrounds, respectively. The course includes principles of potential field theory and introduces the fundamentals of transport. The vector approach, developed in the freshman and sophomore math and physics courses, is used extensively. The other junior course that is somewhat traditional to aspects of chemical engineering is Science of Engineering Materials. In addition to a study of the structure of matter as a physical chemist would approach the subject, there is also included the more modern topic of solid-state physics. This engineering course, different from our Modern Physics course, applies topics familiar to a physical chemist to metallurgical considerations and applies solid-state physics topics to a study of semiconductors.

A strong energy conversion sequence exists within the four years and tends to offset what might be considered a lack of chemistry courses. This sequence may be considered as starting with one year of general chemistry, then includes one semester of physical chemistry for all engineers, a semester of classical thermodynamics, and then in the senior year, a course titled Energetics. Energetics includes direct energy conversion and stresses coupled flow phenomena; its future development will be increasingly towards non-equilibrium thermodynamics. Also in the senior year, every engineering option suggests some energy conversion course. Students in the chemical engineering option take Chemical Thermodynamics and use the textbook by Dodge.

Several other interesting areas that chemical engineering students usually do not develop in depth are Dynamics and Electronic Circuits, both courses given in the junior year at P. M. C. By reason of early and continual use of vectors the Dynamics course is able to treat in depth the kinematics of particles and systems of particles and moments and products of inertia. The course, Electronic Circuits, emphasizes the analytical or system approach to electrical devices. Since the Laplace transform has been developed and used in the prerequisite System Dynamics course, all the time can be spent on engineering analysis of the electrical devices. This is not true of most chemical engineering curricula, where a service course given by the electrical engineering department devotes a large portion of the course developing new mathematics and new terminology with the result that very little engineering is accomplished.

In the senior year, where students now take technical electives for the first time, the chemical engineering option contains four lecture courses and a laboratory course. The outline of technical courses taken by all students in our chemical engineering option last year, the first students to graduate in our new curriculum, is given below:

Senior Year Chemical Engineering Option

FIRST SEMESTER

Equilibrium Stage Processes
Transport Phenomena
Transient & Frequency Analysis
Energetics *(core course)*
Senior Projects *(core course)*

SECOND SEMESTER

Chemical Process Dynamics & Control
Chemical Thermodynamics
Chemical Engineering Laboratory
Senior Projects *(continued)*

Equilibrium Stage Processing is perhaps the most traditional chemical engineering course that we offer. Last year, the instructor used Buford Smith's text of this same title. The contents of our Transport Phenomena course can be visualized best by indicating that the text used is **Transport Phenomena** by Bird, Stewart, and Lightfoot. Moreover, this was one of two texts used by all engineering students in Flow and Fields (the other was an electrical field theory book). As a result, more depth in transport phenomena is achieved in the senior year than in a classical chemical engineering curriculum. In addition, an early grasp of potential fields has aided the students' understanding of the problems presented.

Transient and Frequency Analysis is essentially an electrical engineering course and is a continuation of the sequence of control courses initiated with Systems Dynamics in the sophomore year. The terminal course in this area is Chemical Process Dynamics and Control, which, following a thread of courses dealing with dynamic situations, is quite advanced. This statement is based on a review of material available from the few chemical engineering texts in this area. If the chemical engineering option graduates from P.M.C. are oriented specifically in one area, it is that of dynamic process system analysis and process system control.

While physical facilities for the chemical engineering laboratory have not been completed yet, it will not involve an entirely standard course. The aim will be to initiate creative engineering problem - solving on small-scale equipment. Last year our first chemical engineering option students built a closed-loop controlled heat exchanger, a control system for controlling the pressure of two gas tanks, and a fluid flow experiment involving determination of system response times. This lab will necessarily be under continual development. Senior projects activities oriented towards chemical engineering also provided laboratory experience for our students. Perhaps at this time, it would be best to describe the entire separate laboratory sequence of the curriculum.

One of the new faculty's major initial concerns was the introduction of student internships in engineering through interdisciplinary creative projects. To this end, the faculty initiated a series of Engineering Problems and Projects Laboratories begun in the sophomore year and continued through the senior year. The first in the series is Engineering Problems Laboratory, a sophomore and junior course, which is interdisciplinary and treats lab problems on a short-term project basis. Students solve engineering - oriented problems which require the knowledge gained from theory courses. The students, generally working in small groups, are required to analyze the problem, determine the means for solving it, plan the laboratory attack, select the necessary equipment and instrumentation, perform tests and draw conclusions. Problems are drawn from all fields of engineering and present situations which require the student to develop the ability to think for himself.

The first course given in the first semester of the sophomore year is intended to draw upon the student's background in physics, chemistry, and mathematics and to show the application of these sciences to engineering This lab occurs before the student has had substantial courses in engineering and is intended to motivate and orient him towards engineering, as well as to accomplish the laboratory aims. Several typical sophomore engineering problems are listed in Table I.

Table I. Typical Sophomore Engineering Lab Problems

Torque and Pull of an Automobile *(a 1954 Cadillac was used)*

Measurement of Muzzle Velocity of a Rifle

Velocity and Displacement Measurement of a Vibration Shaker

Measurement and Computation of Mass-Moment and Area-Moment of Inertia

Function Evalutation and Approximation on the Digital Computer

The second and third Engineering Problems Laboratories occur in the junior year and rely heavily upon the student's background (previous or concurrent) in the engineering core courses.

There is no attempt made at fixed subject matter coverage in these labs nor is any attempt made to cover completely all areas of interest in engineering in any one year. Of greater inportance is the engineering attitude, experimental approach, and realization of the limitations .of theoretical models. Some of the problems worked on by students are given in Table II.

(continued on page 31)

R. P. Genereaux
Engineering Department, DuPont Company
Wilmington, Delaware

SPEAKING OUT

ABOUT—Engineering Education and Industry

We engineers are probably the most impatient people on earth, always wanting to change something. We engineers have the finest of objectives in wanting to change things because we consider ourselves creative. After all, there is evidence all around us of our contributions. Our pulses pulse because we want improvement, something better, either in products, or methods, or environment — or in education.

The programs of the national and regional ASEE meetings are impressive, particularly in the breadth of the field of engineering education and the many viewpoints and objectives. Surely everything good and desirable, and perhaps some things bad and undesirable, about engineering education have been discussed many times over. I suspect that both good and bad have been practiced in most schools for years. Yet, I dare to raise my voice in emphasis of a few points because I believe so strongly in their importance.

I am writing as an industrialist. I suspect that words from such a source are not going to cause educators to change drastically, but perhaps they will be of some influence. I speak from thirty-five years of professional experience with a large chemical company. It is said that one of the compensations for age is to be able to brag about one's youth with less likelihood of being contradicted. My experience has included work at the bench in engineering research and in plant design. It has included administrative responsibilities in applying engineering talent to create plant facilities. And for the past ten years I have been exposed to a broad range of management problems concerning engineering for my company.

I value highly my frequent direct contacts with engineering educators over the years since I was in college. Many of these contacts have been in some way connected with the American Institute of Chemical Engineers. I have come to some conclusions, and you may not agree with all of them. What I will propose will involve work. But this does not bother me, for I know from experience that you are not among the multitude who want to get to the promised land —without going through the wilderness.

Whether we are educators or industrialists, we have situations or problems of real concern. I don't profess to know all of the problems of chemical engineering education. I am aware of some because they are basic situations, par for the course. Engineering colleges have fluctuating enrollment and fluctuating demand from employers for graduates. There is a scarcity of good young teachers. There is pressure on the faculty to bring in revenue, to write papers, to win the Nobel Prize, *(or the Walker Award)*, to help their college to be outstandingly attractive to benefactors and prospective professors and prospective students.

The prime job of the engineering teacher, as I see it, is to educate capable young folks, broadening and polishing their many talents, so they can meet the challenges of our economy with maximum effectiveness and pull their weight from the start. I'm told that some students drink deeply at the fountain of knowledge — others gargle.

Industry's prime job is to earn an attractive return on the shareholders' investment by producing and selling desired products. Surely you are impressed by the genius of American industry in making things to last twenty years — and then making them obsolete in two.

Let us face one important fact. Wealth, the wherewithal to pay for all we want in material things, comes only from productive effort, based on the profit motive. Profit constitutes the necessary incentive for competition, which in turn gives birth and nurture to new, better, more available, or less costly products.

I am sure that educators know the importance of free enterprise and the importance of engineers in industry, but I need to have emphasized it here to provide a basis for three assertions I wish to make.

First, everyone in our nation will gain from a better understanding of what engineers do, how they fit into the broad picture of human accomplishment, and how critically important their efforts are.

Second, engineering educators will profit from knowing more fully what industry needs from practicing engineers and what they really do. This increased knowledge might permit them to find solutions of their problems.

Third, the prospective engineer needs to secure an effective education while in college, and he needs to recognize his responsibility in achieving a conscious balance between culture and training.

Let me develop these.

Better Understanding by All

I believe that our nation can profit from knowing better what engineers do and how important their efforts are to our national way of life.

The non-technical population is only vaguely aware of the requirements for technical achievement. The non-technical public will never have and we should not expect them to have a real understanding of technology because real understanding is achieved only by living in it. Therefore, it is up to the academic and industrial interests to supply most of the driving force for the advancement of the engineering professions and its engineers. The non-technical population is heavily dependent on this combination of educators and industrialists to maintain and nourish its economy — to continue it and to expand it through the economic production of needed or desirable commodities.

But some support of our technology is needed from the non-technical population; at the least it is needed from those in the various branches of government, from other professions, and from the press. These people will naturally endorse what appeals to them or what enhances their purposes. They generally ignore the complicated. Glamorous words such as *science* and *space* are easily used. Prosaic words such as *plant design* and *metaphenylene diamine* have little appeal. This doesn't justify our coining new words to add to the confusion; using such jargon as *matrix* when the word *table* is both adequate and understandable. We need to make our field understandable and interesting through reason, not through glamour.

Our non-technical public cannot be expected to discern readily between the technology involved in the space program and that of a chemical manufacturer. But some appreciation of the difference seems desirable. The technical activities supported by the taxpayers are primarily for the creation of items *not-for-sale,* items for use in defense, agriculture, health, exploration, and in communication. In this tax-supported spectrum of scientific and engineering work, economics plays little apparent part and the competitive and profit motives are not obvious. Much of the work is done under the misleading guise of research. Achieving the 100% perfect answer for an item rules the day. In industry, on the other hand, economics plays a major role. Scientific and engineering concepts based on the soundest possible economics rule the day. And we must always remember that the economic base in an industrial venture depends on the demand in the market place. Its success or failure depends entirely on this demand.

If our communications to the general public are to be effective, we engineers had better pay real attention to the use of key words. We should not allow the word *engineer* to be degraded. Most people think an engineer runs a locomotive; no wonder the public glamorizes the scientist. Even engineers are guilty of supporting the myth of all-encompassing science, if it is easier to put across, or seems to give more status. And many scientists might profit by a deeper recognition of the part that engineers play in applying science to the nation's productive effort, to the creation of wealth.

We should reduce the misunderstanding among technical people, both academic and industrial, as to the true application of technology. Improvement would also serve to increase understanding by the non-technical public. I advocate dividing the spectrum of engineering work into appropriate component parts, defining them in understandable terms, and then analyzing each part for the type of talent and experience needed for its proper accomplishment.

This recommendation leads me into my second observation.

Better Understanding by Educators

I believe that engineering educators will profit from knowing more fully what industry needs from practicing engineers and what they really do.

In industry, I reiterate, the profit motive, within certain restraints, is the pervading influence. In the long run the profit motive must prevail, for who can subsidize industry for long? We must not forget that government support comes from taxes which must first be earned. Industry must assure itself in any product venture that there is economic justification, or industry would price itself out of the market.

From the industrial viewpoint, engineering work is carried out in an involved spectrum. This spectrum runs from a base of scientific research through an initial development and economic appraisal stage. Market studies assess the strength of the new product in the market place. Design and operation of a prototype define the engineering basis for the design of the production facility. Rapid design and construction and successful startup of the commercial production facilities are essential for economic reasons and often for competitive reasons. Following initial sales of the product, process and product improvements are essential if the new industrial venture is to stay healthy economically.

For simplicity and understanding of this spectrum, let us divide engineering work into three major categories. The words are generic with no capital letters. These three are research, design, and production.

Research in this connotation — and here I mean engineering research — is more involved with the seeking of facts than it is in their use. As von Karman once said: "*The scientists study what is, and the engineers create what has never been.*" It is in use of the word *research* that we all speak different languages. The needed distinction is not so much in the kinds of research — basic, pure, fundamental, or applied; rather it's in the objective of research — the seeking of facts rather than using them.

Design is the synthesis activity, the combination of scientific and economic facts with practical experience to achieve a successful process and product. Ideas have to be hitched — as well as hatched. A successful process and product means a workable and economical process and a salable product. I can assure you that design or synthesis is involved in practically all development work and that it goes far back into what is commonly called the research stage. Design is the middle of these three categories, and being in the middle between research and production, it is subject to serious interfacial confusion. But intelligent and informed people can reduce the confusion and narrow the band of overlap.

Production is the assembly of manufacturing plant and material, the operation and maintenance of the facility, and the sale of the product. Much of the continuing work on improving process and product, however, remains as a design or synthesis effort.

You and I know that the activities within these three major categories require dissimilar people. They require adverse attributes and talents. We must deal with individual interest, experience, and skill; with intellect, reasoning power, and awareness; with approach to work and the solving of problems. Unless there is a reasonable degree of fit between man and work, both engineer and employer will suffer.

Engineers differ from scientists; economics is the base of all of their technical activities. In the AIChE definition of chemical engineering there is this sentence: "*Engineering is that field of activity where knowledge of the plysical and natural sciences and of economics is applied to useful ends.*"

In the design category, technical calculations take only a small percentage of the time spent. Design engineering involves more than calculation and specifications and drawings. Technical quality, coupled with experience and constant analysis of costs, is required from inception through fabrication of all vital equipment, including its startup and operation.

In some engineering colleges there is inadequate emphasis on dynamics. Some faculty publications in current use still subscribe exclusively to steady-state operation. This attitude is a worn-out convenience. The key parts of design are to provide appropriately for startup and shut-down, and for flexibility to satisfy the future demands of changes

(continued on page 34)

WHAT THEY'RE USING

REVIEW BY *W. H. Abraham*
Associate Professor of Chemical Engineering
Iowa State University

PROCESS SYSTEMS ANALYSIS AND CONTROL, by Donald R. Coughanowr and Lowell B. Koppel, both associate professors of chemical engineering at Purdue University: McGraw-Hill Book Company, New York, 1965. xii and 491 pages. $15.50.

This book was used at Iowa State University in the fall of 1965 for a process control course for all seniors in chemical engineering. It is the most satisfactory text we know of for such a course. The book is well written, in language suitable to its intended audience. In addition, it provides rather more complete coverage of linear systems analysis than preceding books intended for a similar audience. The only major weakness of the book is in the area of application of the theory to actual problems in the control of chemical plant.

The authors have done a good job of explaining the standard mathematical tools of linear systems analysis in simple language. An introduction to ordinary differential equations and some acquaintance with complex numbers are sufficient mathematical background for most of the text. Unfortunately, the necessity to limit the methematical level occasionally makes the book a bit clumsy. For example, the Bode stability criterion is introduced by heuristic arguments rather than as a special case of the Nyquist stability criterion. Also, the Routh test for positive roots is used rather often, but never proven.

The book is well organized for use as a text. There is considerable freedom available to an instructor in the selection of material and the order of presentation. For instance, it would be possible to emphasize either frequency-response or root-locus methods, which are covered independently in some detail. Also, the book is surprisingly free from errors and misprints.

The weakest feature of the book is the lack of information on actual applications of linear systems analysis to real problems in industrial chemical systems process control. This is not caused by lack of effort on the part of the authors. In general, such information is just not available in the open literature. But the lack of adequate information on real control systems makes much of the theory unconvincing to the typical undergraduate student in chemical engineering. The applications that are discussed in the text nearly all show how the theory *might* be applied, rather than showing how the theory *does* apply in industrial practice to the control of chemical plant.

We would not suggest the use of this book at the graduate level, because some important topics are omitted and because the mathematical treatment is limited. For example, computer control is not discussed and such techniques as the maximum principle of Pontryagin or the method of Liapunov are not included.

In summary, this is a good book for an undergraduate course in process systems analysis for chemical engineers. The authors have made a significant contribution by explaining the standard tools of linear systems analysis and some potential applications in language that an undergraduate chemical engineering student will understand. A better book is still needed that will, in addition show how the theory actually is applied to the solution of real problems in the control of industrial chemical plant.

(continued from page 26)

Table II. Typical Junior Engineering Lab Problems

Compaction of Soils
Tolerances in Electrical Components
Thermoelectricity
AC Circuit Analysis
Non-Linearity Determination of Contact Deflections
Transport Dynamics of the Spouted Bed
Performance of a DC Motor
Liquid-to-Solid Transitions
Assumptions of the Theory of Beam Bending
Temperature Measurements in an Expanded Gas System
Moisture Content and its Relation to Density of Soils
Equivalent Networks
Design and Equivalent Circuit of a Transformer
Beating in Vibrating Systems
Equilibrium Phase Diagram for a Cadmium-Bismuth Eutectic Alloy
Flow and Field Plotting on Conducting Paper
Photoelastic Determination of Stress Concentration at a Circular Hole
Thermodynamic Study of an Air Blower Unit

In all labs, the problems are developed and assigned by the professor who advises the students during the three or four weeks of activity devoted to that problem; thus the student will complete four problems each semester. There are no regularly scheduled lab hours for the Junior Problems Laboratory. The students consult with the professor as needed in addition to regular meetings. The laboratories are open day and night, and the student team schedules its own work without detailed supervision. The problems are chosen so that an average of six hours' effort per student per week is required. The sophomores are given more guidance during a regularly scheduled three-hour session.

The interdisciplinary creative projects culminate in the senior year in a true internship in engineering with Engineering Projects. In this activity, teams of three to six students work closely with a "consulting engineer" professor for a year on a complete design and development project which includes actual construction and testing in the laboratory. These design-oriented projects are in a wide spectrum of areas and are generally unsolved problems from current technology. Students must select and purchase their own equipment which includes giving details for specially-machined equipment or writing specifications for purchase orders for a somewhat unique apparatus where in-house fabrication is impossible. A significant part of the student's effort is planning work schedules: for example, planning what literature searches, analysis, and construction can be carried on while equipment is being procured. The professor, as a consulting engineer, recommends certain references, suggests the investigation of certain tests, and the like. Scheduled weekly meetings, as well as impromptu ones, facilitate the professor-student contact.

By completing selection of their senior projects before June, the students may — and are encouraged to — spend the summer in investigatory work. From September until April the students work on their projects in the lab, visit companies for assistance, and perform whatever is necessary to complete the design and construction oriented projects. Project reports are due in April followed by an oral presentation to the Engineering Division, with representatives of local industry invited. The oral presentation has been run as an engineering seminar with an unbiased panel of qualified industrial judges. A significant benefit to the students has been the oral presentation alone. The written final reports, also judged by outsiders, offers another unique opportunity for presenting the students with a realistic engineering situation—that of writing clearly and concisely an overall project report that will be critically judged by their peers.

Short descriptions of senior projects in the chemical engineering area recently completed are:

Sulfur Trioxide Fume Removal

In the manufacture of cooking liquor for pulp making, an undesirable mist of sulfur trioxide is carried through the system and exhausted with tail gases. Several physical demisters for completely removing the sulfur trioxide fume were tested after designing a simulated bench-scale model and developing methods for testing and analysis. Physical demisters proved unsatisfactory for completely removing the fume owing to low partical concentrations and low gas velocities. Of several chemical methods investigated for fume removal, one was found that was effective and economical. The paper mill is making plans, based on the students recommendations, to modify the process. *(This project was financially supported by Hammermill Paper Company of Erie, Pennsylvania)*

A Process for Producing High-surface area Particles

A single processing step was developed and investigated for increasing surface area of raw material particles by forcing the particle slurry through a nozzle under high pressure into the atmosphere. The difference in pressure from nozzle to atmosphere is large enough that volatiles within the particle (absorbed water) flashes off, thus rupturing and expanding particles in a manner similar to puffed wheat and rice *"shot from guns."*

Fuel-Cell Powered Lawn Mower

Various hydrogen-oxygen fuel cells were constructed and tested. It was concluded that the cost of a fuel-cell-powered mower would prohibit its competitiveness at present. This high cost is due to the catalyst-plated electrodes presently required. An investigation of optimum design and reliability was also undertaken. *(This project later resulted in an NSF undergraduate Research Participation grant of $6,250.)*

Flame Tube Studies

A combustion tube was constructed to investigate transient and non-transient uniform flame fields. The tube was designed with all attending measurement equipment; the stainless steel tube was built upon a metal frame, then placed upon a concrete pad and enclosed by three concrete block walls. This tube was fired four times with acetylene gas as the fuel and the resultant combustions were observed.

Shock Tube

An electric shock tube was designed and built to produce shock front velocities up to ten Mach. The shocks are generated by the fast discharge of capacitors into the driver section of the tube.

The interest of senior students in their projects has been tremendous and some real progress in certain areas of engineering has been made. Several patents are being applied for, several industrial companies have paid to sponsor projects of immediate interest to them as a result of knowing the type of work done, and additional companies have indicated interest in next year's projects.

The students have truly had a unique involvement in engineering through interdisciplinary creative projects and the entire aspects of our curriculum. With three years of operation of the new program it is still too early to have accurate feedback from job performance of our students. However, the faculty believes that the program just described will contribute heavily to the future development of these engineering graduates. The authors believe the students have been given a lasting education and have developed a professional attitude.

Editor's Note:
The Appendix on the following page completes this article.

Appendix

ENGINEERING CORE PROGRAM***
PENNSYLVANIA MILITARY COLLEGE

FRESHMAN YEAR

First Semester				Second Semester			
Mathematical Analysis I	4		4	Mathematical Analysis II	4		4
Physics I	3	2	4	Physics II	3	2	4
General Chemistry	3	2	4	General Chemistry	3	2	4
Computers and Engineering Analysis	1	2	2	*Technical Elective			2
English Composition I	3		3	English Composition II	3		3
Physical Education I		2	1	Physical Education II		2	1
			18				18

SOPHOMORE YEAR

First Semester				Second Semester			
Mathematical Analysis III	4		4	Mathematical Analysis IV	4		4
Physics III	3	2	4	Physics IV	3	2	4
Physical Chemistry	3	2	4	System Dynamics I	3		3
Engineering Problems Laboratory I		6	2	Mechanics of Deformable Bodies	4		4
Humanities or Social Sciences Elective	3		3	Humanities or Social Sciences Elective	3		3
			17				18

JUNIOR YEAR

First Semester				Second Semester			
Engineering Thermodynamics	3		3	Science of Engineering Materials	4		4
System Dynamics II	4		4	Electronic Circuits	3	3	4
Dynamics	3		3	Flow and Fields II	4		4
Flow and Fields I	3		3	Engineering Problems Laboratory III		6	2
Engineering Problems Laboratory II		6	2	Humanities or Social Sciences Elective	3		3
			18				17

SENIOR YEAR

First Semester				Second Semester			
Energetics	4		4	Engineering Projects			3
Engineering Projects		9		**Technical Electives (In Recommended Specialities)			12
**Technical Electives (In Recommended Specialities)				Humanities or Social Sciences	3		3
Humanities or Social Sciences	3		3				
			16				18

* Freshman Technical Elective chosen from Engineering Graphics, Engineering Surveys, Computers and Engineering Analysis II, Engineering Instrumentation, History and Philosophy of Science, Biology, and Geology.

** Senior Chemical Engineering Option Courses include: Transport Phenomena, Equilibrium Stage Processes, Chemical Thermodynamics, Chemical Process Dynamics, Chemical Engineering Laboratory, and approved additional courses.

*** Military cadets carry Military Science as an overload (1 credit in each of the first four semesters, 2 credits in each of the last four).

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in capacity and product specification.*

Within Du Pont 28% of all technical people are chemical engineers. The approximate distribution of chemical engineers in the three categories is: research 15%, design 35%, production 50%. This excludes chemical engineers in top administrative and control positions, about 3% of the total. The distribution of all engineers in Du Pont is roughtly: research 10%, design 40%, production 50%. The figures on chemical engineers indicate that we need at least twice as many designers as researchers.

Design engineers engaged in work near the research interface use design principles in evaluating a potential process. The design engineer who is specifying full-scale plant equipment and controls does so by use of a great variety of design principles daily. The design engineer in the process or plant inprovement phase uses his design skills in refined optimizing for economy.

The engineer needs to be able to handle multi-discipline problems as well as multi-aspect problems — problems involving people, scientific principles, experience, economics, and urgency. I cite one example from my experience. The design of the chemical separation facilities for the plutonium plant at Hanford required much more than the chemical research. Under the circumstances of extreme urgency and the lack of either precedence or process, we designed the plant to accommodate almost any process the microchemists might come up with.

I believe that engineering educators have a somewhat different task in the preparation of graduates for the tax-supported type of engineering work than for industrial work. The job of educating the research man is somewhat different from the job of educating the design man. There are now being turned out by the dozens, Ph. D. chemical engineers who have special training in advanced mathematics and whose primary desire is to apply mathematics and computers to chemical engineering problems. The chemical industry cannot today, or in the foreseeable future, utilize all this training effectively.

I believe there is a need to assist the younger chemical engineering faculty, to guide them into making good use of their fresh enthusiasm. There is a need to make more certain that they speak with authority to their students as to what actually is happening in industry, and as to what are the needs for a successful and influential career. How can a teacher teach what industry needs if that teacher has little direct knowledge of industrial practices? While being a consultant will give him some insight, consultant work is not always subjected to the some profit and organizational constraints.

We in industry believe educators will profit by knowing more fully what we do in engineering and what we need in the way of engineering capabilities and thus be able to place your emphasis where it will count. This leads me to my third observation.

Better Balance between Culture and Training

I believe the prospective engineer needs to secure an effective education while in college, a conscious battle between culture and training. An educated man, I'm told, is one who has finally discovered that there are some questions — to which nobody has the answer.

There is nothing grossly wrong with engineering education. Most of the engineering graduates turned out to work are in the main technically well prepared, and can be trained and developed to become engineers. A college education seldom hurts a man if he's willing to learn a little something — after he graduates. I am sure we agree that a college education should aim at developing the whole man, not merely some function of him.

Teaching a trade is not the function of a university; it can be done much more cheaply and quickly in a trade school. A university is designed to turn out men who know how to reflect and to relate, who understand the past and can in some measure anticipate the future, who view the present as something problematic and not as something given, and who also understand duty and responsibility. What a wonderful influence is responsibility! Some people grow under it — others merely swell. A university is designed to turn out men who have a standard of ethics, who will respond to challenge,

* *Editor's Note:* Furthermore, modern design may choose the transient as the normal *modus operandi* for units long viewed as properly steady-state stages.

who will plan and persevere towards a goal. Such a man needs to recognize what he does not know and to know how to deal with this lack of knowledge.

The cultured man is broad, takes an objective view, displays many talents. The purely trained man is narrow, looks to the more specific, is less obviously talented. The largest single defect in character traits is rigidity of mind. Only the broad and flexible personality can cope with new demands and conditions. The qualities of flexibility, imagination, and the interrelation of disciplines are most desperately needed in modern industry. Engineers need to develop capabilities in related engineering fields, especially chemical engineers in the chemical industry because they are generally the lead men.

Only one engineer in five has an easy time in English, in oral and written presentation. The remaining four are really handicapped. What good is expert knowledge if it cannot be communicated? Few new graduates have a deep feeling about economics as a fact of life. In my college experience I learned much from my engineering professors that went far beyond the strictly technical. They wove economics and English composition and reasoning and analysis into their regular courses.

I am advised that college policy-makers have not been outstandingly successful in rewarding good teaching in contrast with rewarding ability to secure research dollars or to write papers for publication. With publication having gone beyond what a man can absorb, perhaps one means for reward could come from the preparation of treatises defining the state-of-the-art on selected topics of engineering. Such treatises could define significant gaps in our technology.

Engineering education should properly be ahead of actual engineering practice. This advanced education should be taught carefully so that engineering students do not stray too far from reality, resulting in graduates that can't be effective in practical work upon graduation.

We must be flexible in chemical engineering to keep ahead of advancing capabilities of computing machines. We must be able to discern between *problem analysis* and *computer programming.* The emphasis on graduate work should not be at the expense of undergraduate teaching.

In deciding what to teach a prospective engineer, it is well to know what tasks he may be expected to perform, and under what circumstances. It is well to know what the key traits are for satisfactory achievement of the assignment. It is important to know what the man is expected to do, not what his work may be called or where his assignment will be in the organization.

In the main, for chemical engineering work in industry, the prospective engineer will need a real capability in problem analysis. He needs exposure while in college to practical problems concerning the synthesis of process facilities. He needs to be able to design instinctively a process or product that has never been designed before. He needs to look at a problem as a dynamic one. Processes rarely operate forever at one set of conditions. Startup and turn down may establish the design parameters, not the full-capacity operation. Now let me summarize.

Conclusion

Our nation can profit if others understand what we engineers really do. We need the support of our entire populace even though we should not expect complete technical understanding. To obtain such support we must take the first step by dividing engineering into its broadest components parts, defining them in understandable terms, and analyzing them for the type of talent and experience needed.

Industry differs from academic and government - supported environments. The profit motive and market competition which bring new products, better ones, less costly ones to the consumer, are the source of wealth which supports all other activities. Appreciation by educators of the spectrum of engineering vital to industrial success can be achieved through down-to-earth analysis of what engineers really do in the basic categories of research, design, and production, as I have defined them. Educators thus would be in a better position to guide the student, and the student would enter his industrial life with better prospects for an interesting and rewarding career.

To you who are engineering faculty members I say: yours is the prime responsibility — to supervise education. I know that many of you are doing, and doing well, the things I have touched on. My plea is that more of you do so, and my hope that all of you will experience increasing support and success in your vital and difficult task. I can assure you that industry is keenly interested in your product. Let us know how we can help you.

A NOTE FROM THE EDITORS

We would like to take this opportunity to offer you, our readers, an apology and beg your indulgence.

Our masthead proclaims publication of Chemical Engineering Education in October, January, April, and June of each year. However, as you are aware, we have thus far sent you only the October issue and this, the January issue, is appearing in June.

For this lack of adherence to schedule we ask your forgiveness. Many circumstances have contributed to the delay, but we hope and believe we have now seen the end of these problems. We expect to have the remaining issues for the 1965-66 year in your hands by the end of the summer. We also expect to be on schedule next year.

Your editors believe that publication of CHEM ENG ED is a vital contribution to chemical engineering education everywhere. We appreciate and need your support; we shall do our best to earn it.

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