ming solution for a two stage system with a single decision variable for each stage was possible because of the availability of the computer programs.

Trouble-shooting problems were used as short case studies where the students played the role of an engineer trying to get a plant functioning correctly for a minimum cost. This innovation was enthusiastically received by the students.

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REFERENCES

1. Crowe, C. M., A. E. Hamielec, T. W. Hoffman, A. I. Johnson, D. R. Woods, R. B. Anderson and J. W. Hodgins, "Teaching Experience from Experimenting with Design and Simulation Projects" paper presented at the ACS meeting. Miami Beach April 10 (1967).
2. Crowe, C. M., A. E. Hamielec, T. W. Hoffman, A. I. Johnson, P. T. Shannon and D. R. Woods, Chemical Plant Simulation Text to be published by J. Wiley and Sons. (1969).
3. Dean, R. C., Jr., P. T. Shannon and S. R. Stearns, Dartmouth College Workshop on Design Education in Hanover, N. H. Summer (1965).
4. Happel, J., Chemical Process Economics, J. Wiley and Sons, New York (1958).
5. Rudd, D. F., and C. C. Watson, Strategy in Process Engineering, J. Wiley and Sons, New York (1968).
6. Shannon, P. T., A. I. Johnson, C. M. Crowe, T. W. Hoffman, A. E. Hamielec and D. R. Woods, **Chem. Eng. Prog. 62**, 6, 49 (1966).
7. Silveston, P. L. and D. R. Woods, "Use of Trouble Shooting Problems in Undergraduate Chemical Engineering Design Courses," paper presented at the 16th Canadian Chemical Engineering Conference, Windsor Oct. 19 (1966).
8. Silveston, P. L. "Trouble Shooting Problems as Teaching Aids" Chap. 4 Chemical Engineering Case Problems AIChE publication (1967).
9. Venus, D. K. **Product Design and Value Eng.** October (1967) p. 36.
10. Woods, D. R. **Chem. Eng. Ed.** p. 19-23 Jan. (1966).
11. Woods, D. R., "The Use of Short Trouble-Shooting Problems" Chap. 3 "Chemical Engineering Case Problems" AIChE publication (1967) and presentation at the AIChE New York meeting Nov. 1967.
12. Woods, D. R., "An Engineer and Communication" McMaster University Bookstore, Hamilton, Ontario.

CHEMISTRY FOR CHEMICAL ENGINEERS*

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The type and amount of chemistry required in the Chemical Engineering curriculum has been a controversial topic over the years. Chemistry is an important part of the undergraduate curriculum and the practicing chemical engineer continues to need a thorough understanding of the fundamentals of inorganic, organic and physical chemistry and the theory and techniques of analytical chemistry. Since he will use chemistry as one of his tools in his decision making processes, the courses should emphasize application and problem solving. His chemical engineering courses in turn should offer him the opportunity to apply his chemical knowledge to the maximum amount possible.

It is a pleasure to discuss with you the very critical question of what chemistry should be included in the chemical engineering curriculum. I think the fact that we are willing to discuss this

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. . . Unwanted or deleterious side reactions . . . will rise up and smite him in both catalytic and recycle processes.

topic is an indication of the dynamic nature of our profession. I also think it is an area that must be approached with some caution. It is true that many chemical engineers are now making noteworthy contributions in areas where no knowledge of chemistry is required. On the other hand, I feel very strongly that a professional cannot be termed a *chemical* engineer unless he has a solid and usable understanding of the major fields of chemistry. Conversely, to be a chemical *engineer* also implies a thorough background in the principles of engineering. These two requirements pretty well define what the technical content of his education must be, and the trick is obviously one of finding an optimum balance between the two.

Before discussing the problem of how much and what kind of chemistry, it might be well to remind ourself of what general procedures will be expected of the chemical engineer on any project he may be involved in. I think in almost any case he would be expected to demonstrate the abilities to:

1. Find and identify the problem or problems in the project.
2. Plan a successful approach to solve these problems using such analytical and synthetic approaches as are required. Problem will usually be open ended.
3. Prepare a sufficient number of solutions (cases) to define alternatives available.
4. Make a decision based on the facts as developed.
5. Report this decision in a clear, concise manner.
6. Be sufficiently versatile to modify this decision on his own initiative when environmental factors change.

While these requirements will not say what kind of chemistry our chemical engineer should study, it does imply how it should be taught. He will obviously be using his chemistry as one of his tools in his decision making. Therefore, all his chemistry courses should emphasize problem solving, and his chemical engineering courses should challenge his chemical knowledge to the maximum. After all, the chemistry department is only responsible for giving him the tools. The chemical engineering department bears the responsibility of showing him how to use them. Accomplishing this objective will require cooperation and much discussion between the departments involved as well as separate and collective discussions between these departments and the users of the product of their labor. Fortunately, as this meeting exemplifies, these informative exchanges are becoming more and more a part of the overall educational process. In passing I think one should give the "Goals" committee and the "Preliminary Report" a lot of credit for stimulating these discussions.

Turning now to the chemistry content of the Chemical Engineering curriculum, I think we would all agree that undergraduate and graduate education will have to be looked at separately. The bachelors degree must prepare a man for beginning positions in industry and government as well as for graduate school. In the former groups he would most probably start in one of the following areas: development, design, operational analysis, technical service, operational supervision and technical sales. To prepare him for this multiplicity of opportunities it seems to me that he must be well grounded in inorganic chemistry, organic chemistry and physical chemistry. He will also require a foundation in the techniques of analytical chemistry. I think it goes without saying that he should obtain these courses as early as possible so that he may start using them.

Inorganic chemistry will, I imagine, continue to be the basis of a freshman course. I would hope that the emphasis here would be on good old-fashioned equation balancing and lots of good experience in handling stoichiometric type problems. Some of the concepts of physical chemistry should also be introduced at this time, but only those concepts which he has the mathematical background to grasp and to apply to problem solutions. While I agree that there may be a real need on campus for a broad, descriptive type of introductory course in chemistry designed to give a student an overall appreciation of the field, such a course should not be considered for the young engineer.

In the field of analytical chemistry one can generate arguments for complete exclusion or very heavy inclusion into the curriculum. My view is a moderate one and I believe the chemical engineer should have sufficient exposure, both theory and laboratory, in the techniques so that he will have a feel for the reliability of these data in his problem solving. I would also like to see considerable emphasis placed on instrumental methods, since these techniques are and will be useful in his in-line control problems.

In organic chemistry there should be a good balance between synthetic and mechanistic work. I think it would be good to place emphasis on some of the problems that will plague him later, such as unwanted or deleterious side reactions. As we all know these will rise up and smite him in both catalytic process and recycle processes. It would also be a good thing for him to obtain an understanding of the effect of structure on physical as well as chemical properties. Many of these men will spend large portions of their careers in product rather than process work.

In physical chemistry I think we would agree that we are looking at the basic science he will use most. Coverage of thermodynamic, kinetic, and equilibrium considerations should be intensive. The only plea I would make is that it be kept general in nature and that we fight the temptations to make it a specialized course in atomic physics, or any of the other attractive fields that have only marginal professional utilization for the average engineer.

In summary, the fields of chemistry and their manner of presentation discussed above seem to me to represent the minimum requirement, and represent somewhere around 30 semester hours of instruction. Additional courses such as biochemistry, colloid chemistry and so on may be highly desirable on an individual elective basis, but do not seem to be general requirements.

The problem of chemistry at the graduate level is obviously much more on a case to case basis. The man who plans a career in process or product research work should certainly broaden his chemical knowledge. On the other hand, the man who aims toward the area of applied mathematics in the separational and diffusional areas may have little need for additional courses unless his local chemistry department is very active in these particular areas. In practice he will probably obtain his additional training in his own department. The terminal masters man going for design has little need for additional chemistry. The same is true for the man aiming for management rather than a technical career. I do not believe that it is really possible to suggest any overall definitive additional chemistry training beyond the undergraduate education. In the final analysis we are engineers, not chemists, and while our problems are involved with process and product, they are engineering problems. Our problems frequently include chemical considerations, but very rarely to the exclusion of all others. In our graduate

I would like to see considerable emphasis placed on instrumental methods since these are useful in in-line control problems.

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training it seems to me that we should provide the chemical training necessary to perform the chemical engineering research or development area the student is specializing in. We should not confuse this with the chemical training requirements of the research chemist.

In summary, chemistry has been and is an integral part of the training of the chemical engineer. He needs to be well grounded in the fundamentals of the principal branches of chemistry. Of equal importance he must be trained in the application of these fundamentals to his problem solving and decision making activities. As he specializes in graduate work, he should be exposed to those branches of chemistry which contribute to his specialization. Finally, we must constantly remember that chemistry is only one of the many tools of his profession, and that his exposure to this science should be in relation to need and not precedent.

ChE news

Dr. Paul Murrill, professor and head of LSU's chemical engineering department, was one of two college professors in the nation to be presented the Faculty Service Certificate by the National University Extension Association's Division of Conferences and Institutes. Dr. Murrill was recognized for a series of short courses which he developed in the area of computers and their uses. A member of the LSU faculty since 1963, Dr. Murrill has also been awarded the $1,500 Halliburton Award for excellence in engineering teaching.

Dr. Richard H. Wilhelm, chairman of the chemical engineering department at Princeton University died August 6. He was the featured educator in the Spring 1968 issue of CEE. Recently he was appointed to the National Academy of Engineering and he presently held the prestigious Henry Putnam University Professorship at Princeton.