lons) and still have a realistic system. Another constraint is having enough space between equipment units for students to move and do their jobs safely. The spacing is largely controlled by the floor plan of a building already erected. We were able to overcome these difficulties without significant sacrifice to the educational concepts.

During the initial phase some final control elements had to be relocated because system response was too slow. Some minor piping changes had to be made in order to accomodate flow rate and pumping requirements.

CONCLUSIONS

- A systems approach to laboratory can be made to work successfully even under the constraints of curriculum limitations and available time.
- Student acceptance has been excellent and the levels of learning high.
- The cost in faculty time has been great but the benefit to the undergraduate student has been worth it.
- As a consequence of this faculty investment in time and the student enthusiasm for the concept, overall student morale within the department has improved.
- Response from both visiting educators and industrial people has been universally favorable.

The results have encouraged us to complete and to improve our original concept for an organic processing line. The students will study different interacting operations including those involved with chemical reactors and kinetics.

We believe that the students participating in Drexel's laboratory will graduate with a firm appreciation of the problems of running an entire processing system. We especially feel that those students who go into design and research will have benefitted by knowing something about systems problems and the interactions of subsystems with each other and with the men who must run them.

ACKNOWLEDGMENTS

The plan for the laboratory was an outgrowth of the philosophy of Dr. Charles E. Huckaba who was at the time department chairman. With his basic ideas, enthusiasm and assistance the support of the National Science Foundation and of the Institute administration was enlisted in the project.

ChE curriculum

CHEMICAL ENGINEERING EDUCATION IN WESTERN EUROPE

CHARLES H. BARRON
University of Virginia
Charlottesville, Va. 22901

In thinking of curricular reform, which seems to be a never-ending chore, it is worth attending to trends that arise and evolve in circle other than our own. With this in mind an attempt will be made to discern directions in which chemical engineering education in western Europe is moving. Many ideas on this subject were presented and discussed at a meeting held in Churchill College, University of Cambridge, early in July, 1968, under the sponsorship of The European Federation of Chemical Engineers. Several of the key points presented at that meeting will be cited, and implications and conclusions will be drawn as they are relevant to the educational

Charles Barron received his chemical engineering education at Clemson University and the University of Virginia. He taught at Tulane University for five years, and he spent the academic year, 1967-68, as a Fulbright-Hays lecturer at the Catholic University of Louvain, Belgium. The following year he joined the faculty of the University of Virginia. His research interests are in the area of homogeneous catalysis and chemical reactor analysis.

scene in the United States. No attempt will be made to review all of the discussion from this meeting. The teaching of chemical engineering within the educational structure of the western European university has developed from a different tradition than that in the United States. If this difference can be identified at all, it is in a stronger affiliation with industrial chemistry.

CURRICULAR CONCERNS

The tone of the curricular considerations was set in the meeting to which reference was made earlier by comments from Professor Sorgato of the University of Padua, Professor Le Goff of the University of Nancy, and Professor Danckwerts of the University of Cambridge.

Professor Sorgato emphasized the importance of minimizing over-specialization and descriptive subjects in the curriculum and went on to add, "One characteristic of our time which will have more and more importance in the future is the fact that on the one hand the technician must often commit himself entirely to the resolution of very particular problems, understood only by a restricted circle of specialists, while on the other hand, he must just as often concern himself with complex problems that involve disciplines that are far from the field of his specific interest." His conclusion was that any form of education that tends to give the student encyclopedic knowledge must be avoided. Following the same line of reasoning Professor Le Goff pointed out that from a pedagogical view the point has long since been passed of arguing about what subjects will be added to the curriculum and in fact the serious problems are now in the choice of which subjects can be omitted. He seemed to have no doubt that a solid mathematical foundation was required for all engineers, and beyond that emphasis should be placed either on the social-economic side *or* on the physical-chemical side of his education. Implementing these ideas in terms of a particular university program Professor Danckwerts made the following remarks relative to curriculum plans at Cambridge University.

"We shall probably be forced to recognize that in the general process of specialization the chemical engineer has ceased to be responsible for the structural or electrical aspects of chemical, or process, plants, and we shall therefore cut out such topics as the mechanical and structural aspects of plant design, mechanical drawing and applied electricity. As for materials science the choice of materials is of course fundamentally important in the practice of chemical engineering, but can one learn enough about the science of the matter in a few lectures to influence one's choice in this to the slightest degree. Is not the choice going to be the product of experience and expert advice"

American faculties might consider electives in applied chemistry such as catalysis, polymers, biochemistry, surface chemistry and electrochemistry.

These ideas from Cambridge are in accord with those from the University of Minnesota, as described by Professor Neil Amundson before an AIChE annual meeting in December, 1966. He expressed the belief that courses in mechanics, strength of materials, electrical engineering, and drafting were on a steady decline and were expected to vanish or at least be reduced to a very minor level.

In discussing the place of economics and social sciences in the chemical engineering curriculum, Professor Danckwerts noted that, "Due to the limitations of time, such subjects as social sciences and economics will necessarily be developed somewhat superficially. The requirements of the normal chemical engineering course simply preclude the development of such subjects from first principles, as we might do in fluid mechanics or thermodynamics. Such superficial development forces these studies to appear somewhat shallow relative to their counterparts in the physical sciences of engineering. For this and other less important reasons, such studies will never contribute as significantly to the education of the chemical engineering student as may be desired by his more mature predecessors." In this subject area Professor LeGoff offered the following comments which support the position given above, "My personal opinion is that economics should be practically absent from the curriculum of engineering and that preference should be given to the physical chemical sciences, for these branches of science are only assimilated with ease before the age of 25. A reconversion to quantum mechanics cannot take place at the age of 40 whereas the taste for economics and human science comes with maturity. The evolution from science to administration is a well known phenomenon in nearly all professions. Furthermore, a conscientious student is much more likely to participate in social and humanizing activities outside the classroom and so can be expected of his own accord to educate himself in these areas. (The student's) prospective mind and his creative imagination must be developed by banishing

all kinds of descriptive and passive teaching in favor of an active formation in comprehension. In other words, we ought to strive more to teach the mechanism necessary for familiarization with new subjects and a certain attitude towards new problems rather than the inculcation of pure fact. This is the one single condition necessary in the student's training if it is to remain valid ten years hence."

As is to be expected, the chemistry content of the curriculum always gets more than passing consideration. Although there was some discussion of chemistry content in the curriculum, none of the authors at the EFChE meeting specifically addressed this question. Professor Amundson did offer his ideas on the subject with the following remarks:

"Most curricula contain little in applied chemistry and this, of course, is the greatest departure from the past, since once chemical engineering meant applied chemistry. I believe the future of chemical engineering is intimately tied to chemistry, and we should find ways to reinforce these two fields to each other in some other context than thermodynamics, chemical kinetics, and molecular transport."

Of course, the normal European program of study in chemical engineering includes more supporting courses in chemistry. In answer to the challenge posed by Professor Amundson, some consideration might be given by American faculties to such courses as polymer chemistry, biochemistry, surface chemistry, catalysis, and electrochemistry, which are often a part of European study programs in chemical engineering. These areas of applied chemistry have certainly developend to the point that substantial courses of study could be devised, and they might be offered on an elective basis to allow students to specialize their own interests.

There was in Europe an undercurrent of belief, both expressed and silent, that the failure of engineering to attract the best students was focing the American universities to turn increasingly to pure science in their engineering courses. The feeling also seemed to be that this change was not good for engineering as a profession. By way of contrast to this position, Professor Le Goff asked the question, "To what extent must the training of engineers be different from that of research scientists?" In developing his answer to this question he cited the impact of the "physical-mathematical revolution" of the 1950's on the education of chemical engineers. "During this period," he said, "chemical engineering evolved

There is increasing throughout Europe a closer communication between the university and industrial practitioners.

rapidly and fundamentally, producing a far greater scientific rigor in the study of industrial processing. Ceasing to be the simple addition of chemistry and mechanics, chemical engineering became an autonomous science resulting from the direct application of physics and mathematics, according to its own method, to what had previously been a field of process chemistry." With this introduction, Le Goff then went on to answer his own question,

"Freed from materialistic tasks by automation, the engineer can now be considered as a researcher: research into improvements, research into the optimal functioning of his plant, research into the material and human means of obtaining results. Thus, his behavior is analogue with that of his colleague in the laboratory, even though his objectives may be different."

By such reasoning, he argued that the research scientist and the engineer should receive similar education, the same foundation based on physics, mathematics, and chemistry, with the engineer receiving an introduction to the synthesis concepts which are so important in his subsequent career.

In the implimentation of curricula to achieve the many objectives previously alluded to, Professor Danckwerts underlined his belief that there was three basic ingredients in a university education—the first of which is *vocational training*. He included in his example of this type of training lawyers, doctors, scientists, and engineers. His second ingredient is *intellectual discipline* or the study of some particular subject in depth. This ingredient is required in order that the student develop habits of rigorous thought and penetrating analysis. Certain parts of every curriculum are to be included for their value as intellectual disciplines and not necessarily for their vocational value. "The final ingredient in a university education is that it should *broaden the mind.* The university graduate should not only be trained in the practices of his professor and in rigorous habits of thought, he should also be aware of the relationship of his subject to other subjects and its significance in human affairs as a whole." In discussing the implementation of curricular objectives Professor Le Goff strongly advocated the increased use of laboratory teaching in order to keep the future engineer in touch with physico-chemical phenomena and the natural imprecision of experimentation.

There seems to be little doubt that the European chemical engineering student has a broader laboratory experience than does his American counterpart. We might find that increased laboratory teaching would be desirable to supplement offerings in some areas of applied chemistry.

Finally in order to accomplish these various requirements, there seems to be increasing interest in several quarters throughout Europe in closer communication between the university and industrial practitioners. This process is occurring at the same time that academic emphasis is shifting more and more in the direction of science and away from technology.

INDUSTRIAL INTERACTIONS

Quite a lot of discussion at the EFChE meeting centered about the cooperation of practicing chemical engineers with educators in certain phases of university programs, and the reciprocal cooperation of educators was called for in some aspects of industrial professional development programs. Mr. H. M. Miller, of duPont de Nemours International S. A., Geneva, keynoted these ideas by citing the advantages from the industrial side of the cooperative, or "sandwich", courses which seem to be flourishing in England. In his opinion such courses effectively create a flow of continuing education into the domain of the practicing engineer. Quoting, "Let me emphasize that these enginering education-industry programs are in no sense charity. Their proponents realize full well that altruism—on either side—will not carry any program past the initial stages of success. They must be joint ventures in fact, validated by perceptive recognition of the waste of going separate ways, of the mutuality of objectives, and of the synergistic results of co-action." He mentioned also that similar advantages accrue to the participants in the so-called partnership programs which certain American universities use in their design courses in association with local practicing engineers.

The need for significant interaction of the university and industry was also recognized to exist in the area of career development. In this activity as well, the advantages were expected to flow in both directions, contrary to the popular view in the United States. The career development of the young engineering professor demands the stimulating influx of interesting ideas and problems from the industrial environment, and similarly the engineering practitioner needs and wants the stimulation of new developments in theoretical understanding. In this way both parties to any cooperative venture can maintain a healthier perspective.

POSTSCRIPT

The American observer of chemical engineering education in western Europe finds several recognizable benchmarks for comparison, but also he finds several trends which are not so obvious in his own situation. A similar optimistic opinion was expressed by Professor H. Blenke of the Technische Ho Hochschule, Stuttgart:

"The development of chemical engineering started and proceeded in the USA and Great Britain on the one hand, and in continental Europe on the other, under different conditions. Thus, the development temporarily moved in opposing directions but with resultant converging trends which lead in our opinion to a considerable agreement between the two concepts. This is not surprising because under the hard criteria of free industrial competition objective, realistic conceptions sooner or later gain the upper hand. Therefore, concepts of science and engineering do not differ more between highly industrialized countries than they do within each country. This is encouraging for it promotes and facilitates the exchange of experiences and cooperation — not only across borders of discipline but also across borders of nations."

On reflection of the many similarities observed, it was surprising to note how little concern there was with the ability of engineers to communicate either in written or spoken words. It is difficult to imagine that this is a problem unique to the United States, but in the EFChE conference confronting problems in the education of chemical engineers not a word was said about this particular problem.

Finally, if any single conclusion could be drawn from the experience of observing the chemical engineering education scene in western Europe, it is that such an activity is extremely educational and is one to be strongly recommended to others.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor W. L. Wilkinson, University of Bradford, for permission to report on the discussion of the EFChE Conference. Professor Wilkinson was the technical program chairman for that conference.