CEE chemical engineering education

CHEMICAL ENGINEERING DIVISION OF AMERICAN SOCIETY FOR ENGINEERING EDUCATION

WINTER 1969

Michigan Educator and White House Fellow

DICK BALZHISER: In the Shadows of Power

Special Issue **THE ENGINEER & PUBLIC AFFAIRS**

LESSELS, BROWN, AHLERT: Technical Careers for the Disadvantaged ● AVERY: Negro and Indian Youth ● TILLER: The University in International Affairs ● BLUM: Directions For Education and Research ● ARIS ● HENLEY

Also GREENKORN *hails* **PURDUE**

SCRIVEN *models the interface*

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Feature Articles

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Recruitment and Human Values

It is well known that the percentage of college students entering engineering has been steadily decreasing while salaries for engineering graduates continue to rise. Why, in the face of economic incentive and improved career guidance materials, are students not going into engineering?

At first it was believed that potential engineering students were moving to the sciences as a result of its better association in the public mind with space-age glamor and its lower requirements for a bachelor's degree. The result was a frenzied pressure to reduce the hours in an engineering curriculum that is expected to produce both a broadly educated person and a professionally competent engineer in four packed years. The purpose was not to improve the quality of engineering education, but merely "to compete". Now however, there are indications that the shift of students has not been into science, but instead into the humanities and the social sciences.

An explanation for this shift can be obtained from an observation that is made by Professor Henley in this issue of **CEE:** In the previous generation, engineering students were obtained largely from less affluent and "blue collar" families. These young men saw, in an engineering career, the possibility of upward economic and social mobility. Today however, the sons of these same engineers are not themselves interested in engineering. Along with many others from higher income families, they are less concerned about material gain and social status than they are about the social and human problems of our society. Professor Henley quite rightly argues that we should improve the flexibility and versatility of our undergraduate programs in order to attract students from the upper classes. But we believe that it is also essential that we recruit more minority group students, who, like those of the last generation, are seeking improved status and living conditions.

We further believe that we need to impress upon the idealistic young men who might be attracted by the social sciences that they can indeed serve their fellow man in a tangible way through an engineering career. For too long we have let the humanists suggest that they are the salvation of mankind and that the "technologists" are the destroyers, the polluters, and the dehumanizing materialists. Instead of using things and loving people, they charge us with loving things and using people.

It is likely that these negative attitudes have developed because our professional goals have not been understood from a sufficiently broad perspective. While our immediate purpose may be to produce improved goods, these are only means to an end, not ends in themselves. Our ultimate aim is to serve our fellow man and to insure him his intrinsic human worth and dignity. Accordingly, if our goal is to serve mankind, it is our responsibility to work to eliminate starvation and to see that the benefits of technology and education diffuse to all peoples everywhere. If our goal is to insure human dignity, we will see that the psychological and economical barriers that inhibit full participation of minority group members in the engineering profession are eliminated. If service is indeed our goal, our profession must then be identified with the prevention of war and social strife through an attack on its causes, with the enhancement of man's freedom (and humanization) through the elimination of drudgery, and with the reduction of pollution through imaginative research.

When we can convince our idealistic youth that the goals of our profession can be thereby implemented and expressed in terms of people and their needs, we should not need to jeopardize the quality of our programs in order to attract more students.

In order to focus attention on these matters, CEE is devoting much of this issue to the subject of engineering and public affairs. Our spring issue will emphasize the related theme "New Directions for Engineering!" Through these two issues, CEE hopes to show that the continued growth of technology need not be feared as a negation of human values, but can instead be construed as an essential component to their survival. —RWF

from our READERS

Editor:

I read your editorial in the latest issue of **Chemical Engineering Education** and found it quite interesting. . . . While I fully agree with everything you said in your editorial I think it should be broadened by leaving out the word "chemical" throughout. Engineering has developed with one root in science, other roots in the engineering sciences, and its trunk is a multi-channel communication cable with branches in operation and equipment design, in laboratories, pilot plants, and processing plants. Its leaves and fruits are products and goods of our consumer economy. Without its roots, it will die; without its trunk, the leaves and fruits will not develop; and without its fruits it has no reason for existence. This is essentially quoted, in part paraphrased, from your first paragraph. I could go on and continue this way throughout.

My point is that we must now begin to recognize the subservience of the adjective to the noun. I think it is time — perhaps past time — for us to accept the fact that we are engineers first and then, oh yes, chemical or electrical or civil or other kinds of engineers including, today, many many with strong interdisciplinary interests and commitments. I think there is *need* for a strong national unified engineering profession, an organization something like the American Association for the Advancement of Science, a journal structure to further breakdown the barrier resistances to communications among various kinds of engineering — the word "kinds" here used in its classical sense.

It seems to me that there is little today which truly characterizes any particular stripe of engineer. I think it is necessary for us to maintain the departments as foci around which engineering schools function but I think it is high time that we recognize and foster, administratively and in the practice of our profession, the idea that we are all members of one profession and that the interactions of engineers of all kinds with scientists, political scientists, economists, humanists, and those from the health professions are NECESSARY if we as a profession are to contribute to the important problems of our era.

I wish we could subscript the adjective the way we use subscripts in our journal articles. We would then have

$\text{ENGINEERING}_{\text{Chemical}}$ or Eng_{Chem} and
$\text{ENGINEERING}_{\text{Electrical}}$ or Eng_{Elec}, etc.
as meaningful designations for our professional identities.

H. E. Hoelscher, *Dean*
University of Pittsburgh

EDITOR'S NOTE: In reply to a letter from the editor, Dean Hoelscher stated that he was not trying to limit chemical engineering, but to express the hope that we will soon realize that engineering must become a single unified profession lest we "fragment ourselves out of the business."

Editor:

I would like to make some comments on Dr. Griskey's opinion"Students, Faculty and Professionalism," particularly his derogatory implications about the University of California at Berkeley.

Berkeley is no paradise for students, particularly for lower division undergraduates; no large computer dominated state school can be. But to imply that the "Berkeley syndrome" is characterized by "staff members that do not care" is to do a great disservice to the many faculty members who are always open, concerned, and interested in the students well being.

As a graduate student in the Chemical Engineering Department, I have had the opportunity to observe the conscientious efforts of many professors seeking student opinions and ideas. Many of the busiest professors — measured in terms of research publications, administrative duties, etc. — are among the most concerned and most helpful.

A *much more important* facet of the Berkeley which I know is that many staff members make an honest attempt to understand the opinions and ideas of their students. We have several men in our department who are quite separated from their students in age, background, life style, and philosophy but yet make conscientious attempts to get an honest view of the student mind.

They are aware that their "professionalism" has not been a final solution to their society's local or global problems. They are also aware that the codes and paths which they have followed with integrity and distinction are not the only ones possible and in fact may not be the best ones for today's young. They often disagree strongly with the actions and ideas expressed to them. But their disagreement is based on their view of the merits of the ideas and actions not on the length of hair or the style of dress associated with them. These men do not view the students as "characters" with "all kinds of weird customs" as does Dr. Griskey, but rather as human beings who are reacting to their own boundary conditions and are trying to solve the problems they see.

Not all nor even most of Berkeley's faculty meet this description. But there are a sufficient number of these journeyman to make life at Berkeley an exciting and stimulating experience.

I would like to cite a recent action by individuals on the Berkeley faculty as one example of the changing attitudes here. This fall, during the turmoil precipitated by the Regents' action against course in which Eldridge Cleaver was to participate, many concerned faculty members and administrators held open meetings in various places all over campus to discuss the nature and the background of the situation. The tone of these meetings was frank and informal; Nobel Prize winners were challenged by first quarter freshmen. This aggressive attempt at communication on the part of these men and the students who helped plan the program goes well beyond Dr. Griskey's "open door" policy.

Finally, I would like to suggest that **Chemical Engineering Education** publish a column giving student views on the issues raised by Dr. Griskey's article, particularly his view of the campus situation.

Thomas A. Massaro, Student
University of California, Berkeley

Letters (Continued on page 29)

ENGINEERING AND PUBLIC AFFAIRS: SOME DIRECTIONS FOR EDUCATION AND RESEARCH

EDWARD H. BLUM*
The RAND Corporation,
New York, New York

Ed Blum, received his BS degree in ChE from Carnegie Institute and the MA and PhD (64) from Princeton University. In 1965, after a year's post-doctoral work, he joined Princeton as an Assistant Professor of Chemical Engineering, where he also served as a member of the graduate program faculty at the Woodrow Wilson School of Public and International Affairs, as coordinator of the graduate program in Engineering and Public Affairs, and as Chairman of the Ad Hoc Committee on Systems Engineering.

In 1967, Ed joined the RAND Corporation as Assistant to the Vice President for Research. Currently, he is a group leader and member of the senior professional staff in RAND's System Scences Department. In addition, since early 1968, Ed has been in New York as leader of RAND's New York City Fire Project, which is engaged in the first comprehensive, systematic study of urban fire protection.

PREFACE

Sometimes by design, more often by default, chemical engineers are becoming increasingly involved in forming and executing public policy. As such areas as public health, resource management, environmental control and weather modification assume still greater social importance, chemical engineers' involvement will continue to increase. Thus, **the question about the professional melding of engineering and public policy is no longer whether it should take place, but how.**

Few engineers now involved in public policy —or, more generally, "public affairs"—prepared formally for their current jobs. Many became active in public policy areas late in their careers, to satisfy professional demand or personal interests. Others, such as the author became involved early in their careers, usually after preparing informally (e.g., through extra courses and reading) or — in some cases — after taking graduate work outside engineering in fields such as law. Although these informal routes have served well thus far, the feeling is growing among those who have travelled them that something better and more thorough is needed.

Two main reasons underly this feeling: professional competence and supply. In the last few years, economics and related social sciences have begun to emerge as semi-practical disciplines relevant to (and used in) devising public policies. Much of the growing managerial "revolution" in Federal and municipal agencies has, for example, been spearheaded by economists and guided by relatively complex economic principles. Although many of the forms and procedures will evolve— and perhaps disappear — the economic precepts (many unfamiliar to engineers) are likely to survive. Similarly, although the effects are yet even less apparent, ideas and principles from other social sciences are being introduced into basic levels of the policy process. Engineers professionally involved in this milieu need to know and understand not only the catchwords of these "new influences", but also their bases and their implications for technical research and design. Professional competence now requires much more than non-technical veneer.

Also, because the current routes are informal and the opportunities often unclear (in most cases, the man still shapes the job, rather than vice versa), too few people choose to follow them. Those who do and, like the author, have need for others, find the supply far less than their demand. Many engineers apparently (from conversations) would like to pursue joint engineering-public policy careers, but either do not know how or are discouraged by the lack of help (or by active opposition) available in engineering schools.

This kind of career obviously is not for everyone, nor should it be. Perhaps no more than several percent of all engineers need be directly involved in public policy, especially if those who are involved are sufficiently sensitive and qualified.

* Any views expressed in this paper are those of the author. They should not be interpreted as reflecting the views of The RAND Corporation or the official opinion or policy of any of its governmental or private research sponsors.

This paper is adapted from a talk presented to Colloquium on Socio-Economic Planning, New York Academy of Sciences, March 16, 1967, when the author was a member of the Princeton University faculty.

What I propose is a concerted effort to develop a meaningful systematic professional discipline (or compound discipline) that will enable us at least partially to understand and control the interaction between people and technology.

But for those several percent, something more is needed. It is to them that the following is dedicated.

INTRODUCTION

Man's relation to technology reflects the root problem of his existence: man has the ability to give form and coherence to his world, even though that world always limits his attempts to do so. Man does not completely control his environment, but neither do the forces beyond his control completely determine his life. Where he can influence his environment, man's actions inevitably reshape his world, whether or not he chooses to direct his efforts toward some conscious goal. When he acts, man implicitly chooses a course and a form for his world; if, as has been his wont, he chooses not to control the course, he may not like the form that results.

Modern cities provide the most conspicuous evidence that technology has too often led life into unduly stressful modes because man has abdicated the attempt to control his own work. The modern city is dramatic proof that people and technology interact whether or not we study or attempt to control that interaction. Indeed, unless we do study an attempt to control it, this interaction between people and technology (which I denote by "engineering and public affairs") may lead to future cities far less liveable and desirable than those we know today. We cannot simply assume that everything will evolve beneficiently.

To direct the interaction between people and technology toward the achievement of objectives man wants, therefore, I propose intensive research and education in engineering and public affairs.

Neither research nor education in this area is totally new, of course; fragmentary efforts exist in many places. Research in engineering and public affairs, often impelled more by necessity than by design, has been carried out in some university planning, economics, and engineering departments, and in some planning and "systems" firms. Education in engineering and public affairs, often called by other names,[1] has been started at several universities, perhaps most noticeably at Stanford (where it is called "Engineering-Economic Systems"), at Dartmouth, and at Princeton. But these efforts, even where they have continued, have frequently been *ad hoc*, faltering, and difficult to evaluate. Very little sense of unity or discipline has yet appeared.

What I propose is a concerted effort to develop a meaningful, systematic professional discipline (or compound discipline) that will enable us at least partially to understand and control the interactions between people and technology. Such a discipline would form an integral part of both engineering and socio-economic planning. Since it is now clearly impossible to point to the best or ultimate forms for engineering and public affairs, I would like to suggest some preliminary directions for education and research.

AREAS OF CONCERN

Although many important problems involving interactions between people and technology arise in the city, I would extend engineering and public affairs' domain beyond the urban region to include topics such as:

Individual and mass transportation, and the interfaces	Waste management
Personal and mass communication	Ecology (in general)
Shelter	Urban problems
Clothing	Large-scale civil planning and organization, including moderinization and development
Recreation	Architecture and construction
Automation	Public Health
Defense	Weather modification
Warfare	Environmental control
Resource management	

[1]A number of universities have programs (usually outside engineering) titled something like "Science and Human Affairs" or "Science and Politics." These vary widely in emphasis and content. Some are devoted to bridging the gap implied by the term "two cultures"; others deal more with substantive issues of mutual interest to scientists (or engineers) and humanists (or social scientists). Programs of the latter type that deal with interactions, rather than just with isolated topics from one field or the other, would for present purposes come under the rubric of engineering and public affairs.

. . . technical and social considerations cannot be divorced . . . it is vital to consider both engineering and public affairs and the interactions between them in analyzing problems and formulating plans and policies

In these areas, technical and social considerations cannot properly be divorced. Conclusions derived from considering only one or the other, or both separately, are likely to be misleading, if not erroneous. First, the assumptions and values inherent in purely technical and social analyses are quite different, indeed often conflicting, and rarely explicitly stated. Thus, meshing the results of separate technical and social considerations without dealing with the interactions is likely to lead to plans and policies beset by internal contradictions and inconsistencies.[1] Such products will satisfy neither the technical nor the social objectives, and will clearly be undesirable.

. . . diverse backgrounds and viewpoints are often quite fruitful . . . invention and discovery often arise at the boundaries of special fields . . .

Second, and perhaps even more basic, considering engineering and public affairs separately is likely to prevent proper definition of the problem to be solved. Social scientists and engineers both have attitudinal and methodological bases that cause them to frame and examine problems in certain traditional ways. Since social scientists generally have had little to do with engineering (or science, with the important exception of those who have examined the politics of "big science"), they are often inclined to accept the statement of the technical problem, and the "feasible" solutions, as given. Similarly, engineers are inclined to regard the statement of the non-technical part of the problem also as given, and hence exempt from questioning and reformulation.

Since neither social scientists nor engineers are accustomed to dealing with the other's specialty, the most important parts of the problem statement may fall between them, accepted by both without questioning as the other's concern. Even if the problem is sufficiently conventional that its technical and social aspects are well understood, the social scientists and engineers, by failing to question each other's part of the problem statement, may end up solving totally different problems. And each may, by concentrating on the points most interesting to him, ignore the interactions between engineering and public affairs that may be more important than either alone.

Thus, in the areas listed above, it is vital to consider both engineering and public affairs, and the interactions between them, in analyzing problems and formulating plans and policies. It would also appear valuable to consider the compound field, including the interactions, in research. Drawing on a compound discipline may enable one to recognize weaknesses in current arguments and current practices that professionals in the particular fields have "learned to live with" or disregarded. Indeed, diverse backgrounds and viewpoints are often quite fruitful within engineering and the natural or social sciences; invention and discovery often arise at the boundaries of special fields, as the growth of astrophysics, biochemistry, bioengineering, mathematical economics, etc., will attest. It would not be hard to imagine similar or perhaps even greater innovation occurring at the boundaries of engineering and public affairs.

(Dr. Blum discusses Directions for Education and Research beginning on page 38)

[1]A technical package consisting of many components may be (and often is) assembled and "optimized" according to criteria quite incompatible with those desired socially or potentially, e.g., minimum short-terms direct cost (ignoring benefits, long-term costs, and indirect "social" costs), technical efficiency (related usually to one scarce input, ignoring all other scarce inputs and the costs and benefits of outputs), maximum production, etc. Even if the criteria are explicitly stated, which they often are not, they are so different from the criteria used ordinarily in public affairs (equitability, benefits to special groups, scope for individual initiative, etc.) and use such different scales that reconciling discrepancies is extremely difficult.

First, it is often hard even to recognize where conflicts exist, because the criteria are expressed in different terms which refer to different value systems. Second, since the technical and social alternatives are usually offered as complete packages, within which compromises and trade-offs have been made according to the respective (different) criteria, it is difficult to extract from the total packages parts compatible with over-all criteria. Even if one can dissect the different packages to obtain compatible parts, one has no assurance that the parts will function well together as a system.

ChE educator

DICK BALZHISER OF MICHIGAN

This feature article was contributed by Professor Stuart Churchill, University of Pennsylvania and former chairman at the University of Michigan.

The students and faculty of the Department of Chemical and Metallurgical Engineering of the University of Michigan have a proud tradition of active participation in athletics. Many students, and usually superior ones, have won recognition in formal intercollegiate competition. Bob Bird recently stated in **CEE** that the faculty of Chemical Engineering Department at the Univsity of Wisconsin confines its athletic interests to canoeing and golfing. The faculty at Michigan choose more vigorous sports, including skiing (one member even has a row-tow in his backyard), tennis (they challenge all other departments at the annual AIChE meeting), ice-hockey (several have backyard rinks for practice), touch-football, basketball, baseball, squash racquets, and handball.

Dick Balzhiser fitted quite naturally into this environment both as a student and later as a faculty member. He completed his baccalaureate in four years, ranking at the top of the entire class of 800 in engineering, and still found time to play varsity football, to take an active part in an incredible number of other extracurricular functions, and to support his family (which then included two children) by working as a research assistant.

He did not secure the position of first-string fullback until the middle of the second season because the coaches were somewhat distracted by the priority he gave to laboratories over football practice. However, once given a chance to play he demonstrated his superiority in spite of limited practice.

As an undergraduate he did not receive financial support related to his athletic activities. However, when he began graduate work he secretly accepted a position as Assistant Freshman Football Coach (primarily as an excuse to be out on the practice field every fall afternoon). We became concerned that this responsibility might impede his doctoral work and awarded him a Fellowship the next year with the proviso that he stop such "moonlighting". We presumed he had resisted temptation until the coach credited the upset of Iowa's championship team to the superb job of scouting done by Dick. Dick was embarrassed but rationalized this misdeed on the basis that he had refused to accept any payment and had driven his own (very old) car to Iowa City.

Despite such diversions Dick completed his doctoral work in due course. He has since done an outstanding job of teaching and research, receiving numerous awards. He has also found time for scholarly, professional and administrative work, and to provide leadership in an amazing list of community, religious, business, social and political activities, culminating in a term as Alderman and Mayor Pro-Tem of Ann Arbor and in a year in Washington, D.C. as a White House Fellow.

It is hard to predict what Dick Balzhiser will do next. What ever it is will be well-done.

Biographical Material

Dr. R. E. Balzhiser is professor of chemical engineering at the University of Michigan. Along with his athletic letters he also holds BS, MS, and PhD degrees from Michigan. His teaching career started as instructor there in 1957 and his outstanding teaching and research activities resulted in promotion through the ranks to professor in 1967.

Among the honors and awards received by Dick the following are mentioned most frequently:

Western Conference Award (Big Ten) for proficiency in both athletics and scholarship
Outstanding Young Professor in College of Engineering
Outstanding Young Man of Ann Arbor, Junior Chamber of Commerce Award
Elected Mayor Pro-Tem by fellow councilmen
Outstanding Young Man of Michigan (one of five)
White House Fellow

Dick continued his interest in nuclear engineering as project director for over $600,000 of research work for the Atomic Energy Commission and the Aeronautical System Division in liquid metal technology. He is a consultant to a large chemical company and editor of a "Chemical Engineering Series" of textbooks for a well known publisher.

Some of Dick's activities and experiences as a White House Fellow are detailed in the next article. While in the Defense Department he assisted in organization and incorporation of Alliance for Civic Action, a group concerned with the nondestructive application of military resources to society's problems.

The White House Fellows Program was established by President Johnson in 1964 to give rising leaders from all fields one year of "firsthand, high-level experience with the workings of the Federal Government.

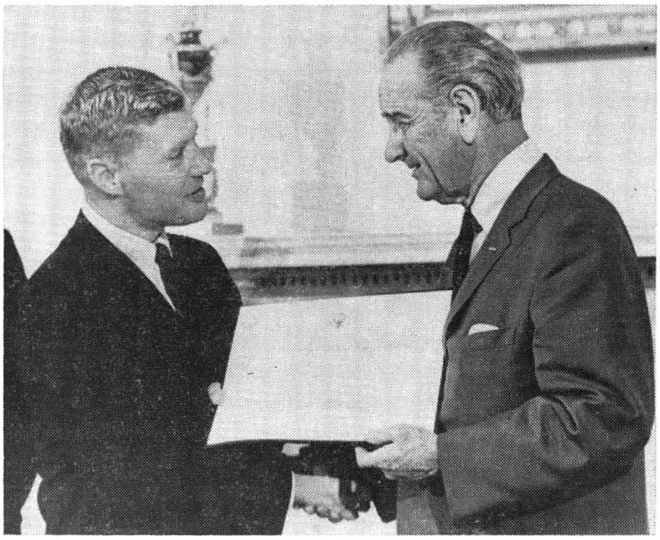
IN THE SHADOWS OF POWER

RICHARD E. BALZHISER
University of Michigan
Ann Arbor, Michigan

Historians will long reflect on the eventful period through which this nation recently passed. It is doubtful that any period in the nation's history has produced, with such prolific regularity, events with the profundity and gravity of those occurring between August 1967 and November 1968. From the burning of Detroit to Richard Nixon's election to the Presidency, this country has experienced the tragedy of asassination, a confrontation with the Poor, the frustration of a Pueblo, brinkmanship in Cyprus and the Middle East, the commitment of troops to streets of our cities, the near collapse of the world's economy, a struggle with both friend and foe in Vietnam, the surprising exits of Lyndon Johnson and George Romney from the Presidential race, the hope of arms control, the brutal display of Soviet insecurity in their invasion of Czechoslovakia, and an unprecedented test of our democratic political processes.

DURING A MAJOR PORTION OF THIS historic period from September 1967 - August 1968, it was my privilege along with fifteen other young men and women to serve as White House Fellows in our nation's capitol. We were the third such group to spend a year in the shadows of power that radiate from the White House. The program was initiated by President Johnson in 1965 with the stated purpose of exposing young potential leaders to the decision-making process at the top level of the federal government. Each Fellow is assigned to a member of the President's Cabinet or to key Presidential advisors in the White House.

Superimposed on this assignment is an extensive educational program consisting of numerous meetings with the President and his major advisors, senators, congressmen, board, bureau and agency heads, governors, mayors, corporate, university and union presidents and officials, ambassadors, columnists, and civil rights leaders. These meetings were supplemented in the past year with two field trips to New York which provided an opportunity to meet with Mayor John Lindsay and his staff, residents of ghettos, some of the young militants of Bedford Stuyvesant, the editors of the New York Times, David Rockefeller and his associates in the Chase Manhattan Bank and the Urban Coalition, McGeorge Bundy and officials of the Ford Foundation, and Secretary General of the United Nations, U Thant, and several foreign UN ambassadors. Without exception, our discussions were frank and productive and provided each of us with an incomparable exposure to the problems and personalities of our nation and the world.



MY ASSIGNMENT WAS TO THE Secretary of Defense where I was fortunate to serve under two of the nation's most capable men, Robert McNamara and Clark Clifford. Robert McNamara's philosophy of involvement was quickly and clearly spelled out my first day at the Pentagon. Observers had no place in his office; understanding required immersion in the affairs of the department and it was to that end that he urged me to select specific projects and commit myself to a year of action not merely observation. I soon came to find that indeed the Pentagon under Robert McNamara (particularly his immediate staff offices) was a beehive of activity from early morning to well into the evening hours, interrupted only by an occasional half hour trip to the squash courts to maintain the physical and mental edge required to operate under the tremendous pressure that confronts defense officialdom.

Few Americans fully appreciate his (McNamara's) deep sensitivity to the social problems of the world and his long-standing commitment to their resolution.

The McNamara record is far too long and the man much too complex to discuss here in depth, but I feel compelled to share several of my observations. Most acknowledge (including his adversaries on Capitol Hill) his brilliant mind, the computer-like precision with which it functions, and his almost infinite capacity for work. Few Americans fully appreciate his deep sensitivity to the social problems of the world and his long-standing personal commitment to their resolution. He consumed valuable "political capital", both with the military and the Congress, in his efforts to correct those social injustices which he felt were properly a concern of the Defense Department.

His move to the presidency of the World Bank might have been anticipated by one who studied his Montreal speech of May 18, 1966, "Security in the Contemporary World", in which he related world security to the economic development of the lesser developed countries in the world. My personal disappointment in his departure from Defense was tempered by the realization that his talents would become focused on this important problem.

Much speculation surrounded this move, but it appeared to me one that was clearly advantageous to both himself and the President. He had served longer than any of his predecessors in this most grueling position during a most turbulent period of our history. He appeared anxious for the shift in emphasis afforded by the bank presidency. The President, while retaining his highly regarded counsel on an informal basis, was clearly in a position to begin to ease the tensions that had developed between his highly principled Secretary of Defense and the House Armed Services Committee in recent years. These differences had contributed to the deterioration in relations between Congress and the White House which jeopardized the needed tax bill and other high priority legislative needs.

His appointment of Clark Clifford proved to be another example of the political genius of Lyndon Johnson. The new Secretary appealed to the hawks and doves alike, as well as the military and the Congress. Taking full advantage of the greater flexibility that a fresh appointee possesses, Secretary Clifford proceeded to resolve skillfully the sharp differences in matters such as the nuclear frigates, authorized by Mendel Rivers', House Armed Services Committee, but never built by the Defense Department. He likewise aided substantially in achieving the spending cuts within the Defense Department necessitated by subsequent tax action in Congress.

Monday morning staff meetings under the latter were a sharp contrast to those under McNamara. Briefing by junior officers were replaced by a frank discussion of timely issues facing the Department. Interaction among senior civilian defense officials and the Joint Chiefs of Staff picked up noticeably as did the enthusiasm of all participating. Decisions were seldom made during these weekly sessions, but the exchange of ideas that took place was invaluable to me in better understanding the attitudes of key participants on important issues before the Department.

THE MAJORITY OF MY EFFORT IN THE Pentagon was devoted to two assignments. The first consumed seven months and involved participation in an all-encompassing study of our Vietnam commitment. My observations and conclusions based on this experience alone could easily comprise a volume. Without undertaking such a task here, let me simply say that our efforts in that corner of the globe were placed in much better perspective by this assignment. I found our motives, if not always our means, to be completely defensible in virtually every instance. Individual decisions by each of four administrations seemed quite reasonable when evaluated in the context of the period in which they were made. However, the decisions of today must not be prejudiced by those of the past; we cannot, regardless of the resources we commit, make the Vietnamese government a viable political entity by our actions alone. This is clearly their responsibility, and our commitments must be made with regard to their ability and willingness to carry out the reforms necessary to win the broad based support of the people. At the same time our pressing needs at home and elsewhere in the world cannot be ignored in such decisions. With these factors in mind, I welcomed the eventual decision by the President to suspend the bombing and hopefully move closer to a negotiated settlement of the bloody conflict that has wearied several generations of Vietnamese people and sharply divided two generations of Americans.

For the final five months of my tenure in the Department, I served as Executive Secretary of the Civil Disturbance Steering Committee, an advisory group established by Secretary Clifford to work with the military in planning and programming the use of military resources for civil disorder control. It provided an excellent exposure to the methodical manner in which the military responds to the chain of command emanating from the White House. Activities in this assignment ranged from formulating the agenda for Steering Committee meetings to attending daily brifing sessions with officials from the District of Columbia, the National Park Service, the Justice Department and the White House throughout the tense period during and following the Poor People's Campaign in the Capitol.

Both assignments provided an excellent opportunity to contribute to the decision-making process. Integration into each of these positions, while awkward at times, proceeded with remarkable ease considering my somewhat unique position in the Department. I was aided considerably by the involvement of my predecessors, a respectable civil service rating in the Department, and the recognition and respect automatically shown for one housed in the Secretary's suite of offices with a White House appointment.

In many ways the White House Fellows served as sort of shadow cabinet. Individually, we became well informed on many of the major issues confronting our respective departments. We communicated frequently with one another, in some cases, on a more regular basis than the senior Cabinet officials to whom we were assigned We were unencumbered by administrative assistants and the bureaucratic channels, and thus were freer to interact than officialdom itself. The very nature of our role provided us with ready access to many issues, programs, and concerns that were percolating through the system. We had daily contact with people at all levels within each department so that we often saw sides of an issue that were blurred or deleted by the bureaucratic massaging to which most matters are subjected. The process frequently enhanced communications within the departments to which we were assigned, in that we crossed lines of authority and areas of responsibility that full-time employees were unable or were not expected to bridge. In this way, our contributions were frequently difficult to define, only occasionally recognized, and generally best left unclaimed.

In many ways the White House Fellows served as sort of a shadow cabinet.

To be certain, we observed the often cited weaknesses of a gigantic bureaucracy groping to deal effectively with mounting problems at home and abroad. At the same time, we observed a remarkable array of talent, laboring with dedication and conviction, to meet the constantly emerging problems of the nation and the world. Without exception, we developed a peculiar sense of loyalty and respect for the man or men under whom we worked. We came to know government as a collection of humans and not an assemblage of buildings and institutions located on the shores of the Potomac. We found it subject to frailties and prejudices of humans just as the corporations, institutions and firms from which we had come. Names became people and pedestals became desks, across which most of us sat at one time or another. The decision makers suddenly appeared as men upon whom unbelievable pressures were constantly imposed and who recognized the limitations and uncertainty which surrounded each decision that flowed from their office. It is indeed difficult for us to take for granted any longer the processes by which the government interacts with its people, with its institutions, or with other nations.

I'm sure that my experiences were shared by my colleagues in their respective departments. To some we were looked upon as intruders or opportunists, somewhat idealistic in our approach to the problems of government. To others we represented a breath of fresh air and hope for the future. To John Gardner we clearly were the manifestation of an idea which he had conceived before joining the President's Cabinet. To the President, we represented a link to the generation with which he has had the most difficulty in communicating. The program was clearly a gamble for him, but one that he took with a great deal of enthusiasm and hope. The 68 of us, who have been fortunate enough to experience the enlightenment of involvement and commitment to the future, believe we have fulfilled his confidence and expectations. As he told Mrs. Johnson, . . . "when Lyn and Lucinda first vote, I hope they will be voting for a member of this Association." To those of us who served in the shadow of the President of the United States, that is the ultimate in compliments.

TECHNICAL CAREERS FOR THE DISADVANTAGED

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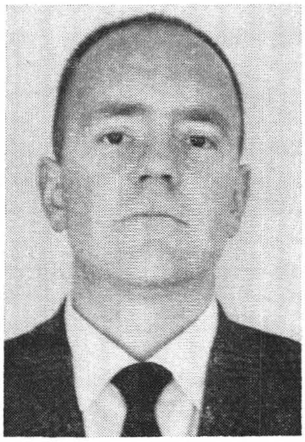


G. A. Lessels received his BS in ChE Practice from MIT in 1950. He is Manager of Process Development for the Coatings Division of Mobil Chemical Company in Edison, New Jersey. He is active in AIChE nationally and at the local section level, currently being chairman of the national career guidance task force for disadvantaged youth which developed the material in this article. He is a licensed PE in Ohio and Illinois, and has published papers covering technical areas and subjects relating to professionalism and management.

The need to provide career guidance of a special kind for underprivileged and disadvantaged youth is heavily documented. The problems of ghetto dwellers—transmitted at an early age to their children—is told in such reports as the one by the President's Commission on Civil Disorders. Unfortunately, professional career guidance has almost always been directed to the middle-class school, whether urban or suburban. The rural slum and city ghetto provide very little motivation to children and lead to an unreceptive audience. Study shows, in general, that the occasional Negro or Mexican-American Chemical Engineer did not come from a completely deprived background. There was generally a parent or relative who got across the value of a good education. The comparative absence of minority chemical engineers is a result of many things: discrimination, apathy, financial deprivations and poor communication.

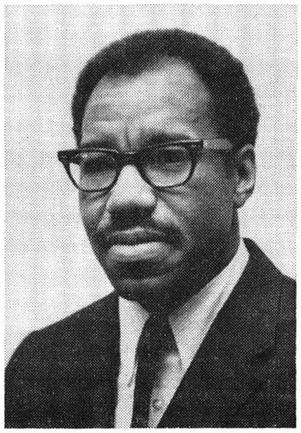
Recognizing the need for a special approach and program, the National Career Guidance Committee and AIChE appointed to Task Force on Career Guidance for Disadvantaged and Underprivileged Youth in early 1968. The initial mission of the Task Force was to define the role that a national professional society might play in guidance of disadvantaged youth toward science and engineering careers. The Task Force included interested white chemical engineers and several black chemical engineers possessing personal familiarity with the problems of the disadvantaged.

In May 1968, the Task Force presented its recommendations to the National Council of AIChE. Major emphasis was placed on a statement of objectives, to be adopted as an expression of purpose and relevance by Council. This recommendation was accepted and resulted in the following commentary:

"Since AIChE already has a strong career guidance role, the Institute fully endorses the concept of local section programs to encourage underprivileged and disadvantaged youth toward professional and technical careers in science and engineering. No longer should extensive human resources go untapped because of artificial barriers or poor communications — particularly at a time when there is an increasing national need for scientific talents.

'In addition, we as members of AIChE are sorely conscious of the deepening racial division within our country, and of the enormous effort that must be expended to alleviate the continuing polarization of the American community. We realize that positive steps must be taken to solve the problems of the underprivileged, and we would like to contribute to the long-term solution."

The Task Force recommended, in addition, that its mission be broadened to include development of means for practical progress toward these objectives. As a result, the Task Force was invited to under take the job of defining and establishing methods and techniques that could be implemented by Local Sections of the Institute. Further, it was asked to coordinate Local Section activity and to function for the period of time necessary to modify the program in response to experience and level of acceptance.



Henry T. Brown is senior research engineer at Squibb Institute for Medical Research, New Brunswick, N. J. He received the ChE from University of Cincinnati and MS from MIT in 1956. For ten years he was associated with Esso Research and Engineering and presently is also an extension course lecturer in School of Pharmacy, Columbia University. His activities include research and development of processes with special interests in fermentation, solid support catalysts, and ion exchange.

By September 1968, a program had been completed and was endorsed by AIChE Council. This program stresses a maximum of flexibility in order to best suit the needs of the particular community and local group. Key aspects of the Task Force "package" are presented in the following discussion.

WHAT SHOULD BE THE APPROACH ?

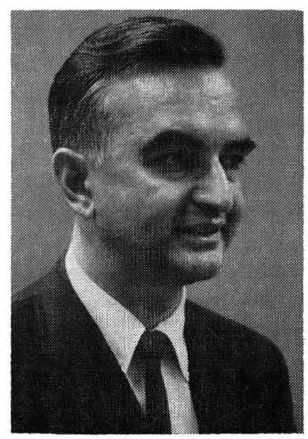
The approach that is utilized to institute a career guidance program will largely determine its success. To have an effective program, existing career guidance activities must be modified to recognize the needs of underprivileged and disadvantaged youth. While no one plan may be applicable for each and every area, certain approaches should ease the task of implementing a program suited to the individual needs of the community. It is highly recommended that local groups direct their activities to areas with high concentrations of the disadvantaged and underprivileged. These are the communities where traditionally the needs are greater and the career guidance activities are weak, minimal, or possibly non-existent.

In most cases the best approach for the local group is to enlist support of local industry, establish ties with community, minority and equal opportunity groups, and work through the ghetto schools and school officials. Where possible, Chemical Engineers will find it advantageous to work with other professional societies who have active programs in this same area. **In all cases minority members of the Institute and other technical minority personnel must definitely be involved to the fullest extent.** Cooperative efforts with industry, the school, and community groups should permit maximum gain for the youth from limited resources and manpower that are available to most local groups. Many of these groups, in addition to oflering their experience and talents to the program will help to bridge any communication gap with underprivileged youth and guarantee continuing support of the program.

COMMUNITY INVOLVEMENT

Recognition of minority community organizations, their leader, and their goals *must be* a part of the local group's program. if counselling is to be successful. The approach should be the same as used for any other community project that requires action — people must be made to feel a part of the program if they are to act cooperatively to pursue the program's goals.

In most cases the internal structure of organizations that aid disadvantaged and underprivileged groups, provide for programs of education and counselling of youth. Many prefer working through the communities' school. As examples, with respect to the black community,



Robert C. Ahlert received the BSChE from the Polytechnic Institute of Brooklyn, MS from UCLA and PhD from Lehigh University (1964). He gained the greater part of his industrial experience as a research engineer and supervisor for the Rocketdyne Division of North American Rockwell. In 1964, he joined the staff of Rutgers University as Executive Director of the Bureau of Engineering Research and Associate Professor of Chemical Engineering. His interests include combustion, the thermodynamics of condensation from gas mixtures, and simulation of stream processes.

Industry involvement is important to the program's success. Local groups are encouraged to solicit support for both manpower and for adoption of programs affecting employment of the underprivileged.

the Urban League has the "Tomorrow's Scientists and Technicians' (TST)" program, CORE has an education committee, the NAACP has youth and education committees, and many anti-poverty agencies and newly formed urban coalitions have educational programs for the disadvantaged. All committees have programs aimed at counselling underprivileged youth. The more militant Afro-American, Black Pride, Black Nationalist and Black Power groups place a strong emphasis on education of black youth and have committees that function in this area. Depending on the local situation, the latter groups may have broad contacts with youth and must not be omitted when trying to set up a meaningful career guidance program that will enhance confidence. The organizations cited are for illustrative purposes; similar considerations apply in dealing with any minority group organization.

It is naive to expect *only one leader* or *only one opinion* from a minority community, just as no one opinion or one leader can speak for all other Americans. In most cases, the goals may not differ between groups, and what really matters is the ego or the personalities involved.

USE OF THE GHETTO SCHOOL

The ghetto school should be a prime target. To obtain the greatest exposure possible, career guidance activities are best undertaken at the school or at a location inside the ghetto area. Programs that reach elementary disadvantaged youth are definitely recommended and should be encouraged. Such contacts would stimulate awareness and motivate youngsters to obtain the high school background that is required for admission to a technical school or college. One such program is the Cincinnati Saturday Enrichment Program which combines career guidance with some remedial assistance. Without such programs, engineers who visit high schools in underprivileged areas will find it difficult to communicate or stimulate interest in science or engineering. The occasional high school student who is motivated by this late contact will be poorly prepared to pursue a college course. It is important to develop good working relations with school officials—particularly science teachers and guidance counsellors. Prior contact with state and local school officials, and professional guidance societies may help to establish proper rapport. The main point to emphasize is that industry and professional societies provide equal opportunity in science and engineering careers, to all who are qualified, and are encouraging youth to take advantage of these opportunities.

THE ROLE OF INDUSTRY

Industry involvement is important to the program's success. Local groups are encouraged to solicit support for both manpower and for adoption of programs affecting employment of the underprivileged. Industry must encourage participation of professionals in the program. Unfortunately, some professionals from minority groups have disassociated themselves from such an activity over concern for unfavorable publicity for their employers. Once corporate sanction is given, the stigma is removed, and the man no longer feels trepidation over activities that deal with his minority group.

Plant tours for underprivileged youth is another area where industry's help is needed. During the tours emphasis on opportunities that are available, with examples of technical jobs held by minority group employees, helps to convince these youth that there is more than talk involved.

Industry can provide part-time and summer jobs for the underprivileged to furnish funds for students in need of assistance to complete their education. In some instances, jobs that have involvement with science can be made available as aids to motivation. Of course, state laws on minimum employment age must be observed in programs like this.

PRESENTING THE PROGRAM

When presenting materials to these youths, it is important to recognize that there exists a wide distribution of attitudes and talents. The two extremes encountered may be:

> Those young people who are bright and adjustable but who are poorly motivated to seek an improved status in life,
> *versus*
> The frighteningly large group who can barely read or write and whose attitudes are so atrophied by social or economic conditions that basic communication is difficult.

The need is so great for technical people that all groups constitute an untapped reservoir of talent and technical ability. Industry can ill-afford to pass over such talent in a period of technical manpower shortage . . . the development of these human resources is an appropriate reward . . .

While the differences are more pronounced among high school students, the problem exists even at the grade school level. An effective motivation and career guidance program must be geared to provide for both groups of students and, hence, must be tailored for the needs of the area served.

Minority youth may question the credibility of programs instituted by predominately white organizations. This attitude has been created by the failure of some highly publicized programs which are nothing more than "show case" efforts in this area. A recent article in the *Harvard Business Review** points out some of the reasons for skepticism, which make any white-oriented or middle-class program, regardless of its benefits, subject to failure. Hence, the inclusion of minority group professionals and technicians in planning and presentation should be a requirement that is not taken lightly. Students will be able to relate and respond better to successful minority workers. Local groups must also be prepared to answer questions that may arise from students with relatively aggressive attitudes.

The level of the presentation should be the same as for any youth of similar age. The youngsters should leave with some idea about what an engineer or technician does, what are his qualifications, and what are his rewards. The main point to communicate is that there are opportunities in technical fields for everyone who is qualified. The need is so great for technical people that *all* groups constitute an untapped reservoir of talent and technical ability. Industry can ill-afford to pass over such talent in a period of technical manpower shortage; there is no economic justification to exclude anyone with these particular skills.

Generally, the series of program steps used to implement career guidance for the disadvantaged and underprivileged are not fundamentally different from other programs in this area. They include:

* Haynes, "Equal Job Opportunity: The Credibility Gap", Harvard Business Review, July (1968).

- Developing an awareness, an interest, and a knowledge of careers available in science and engineering through talks, posters, films, and scientific presentations. A large number of pilot talks, panel discussion outlines, booklets, film lists, and "A Chemical Magic Show" are available.
- Sustaining interest — this may be accomplished by the assignment of an engineer or a scientist to a particular school to deal with specific problems or projects in the school. School science clubs centered around youngsters with strong interest should be organized to act as a nucleus for expanding interests and motivation. In addition, groups should encourage programs that allow individual contact with high school students and tours of industrial plants.
- Supporting in-school career guidance — Provision should be made for specific assistance for guidance counsellors and science and math teachers so that they can speak authoritatively to students about technical careers.

Help for students may be required in a number of ways. Students who are motivated may be inadequately trained. In such cases, the local group should work with school and college officials to set up required supplemental programs. College scholarship funds, for most students, must be identified. Also, summer and/or part-time employment must be secured for students in need of resources to complete their education.

PROSPECTS

Many Local Sections of AIChE are well along with programs of the type proposed. However, the results of these activities will be uncertain for many years. In the near future, acceptance by minority communities and improved communication with the youth of urban ghettos and rural slums will be positive evidence of progress. The real goal of more minority group scientists and engineers will be many years in attainment. Sustained effort and continuing innovation will be required for a relatively long period, but the development of these untapped human resources is an appropriate reward for Chemical Engineering and allied professions.

ACKNOWLEDGMENT

Special acknowledgment is due Messrs. H. A. Abramson, A. F. Stancell, and T. Tomkowit of the AIChE Task Force for their contributions to the preparation of this article.

ENGINEERING OPPORTUNITIES FOR NEGRO AND INDIAN YOUTH

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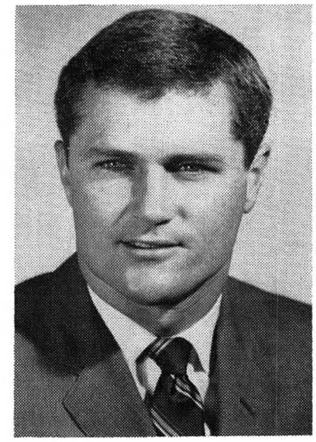


Bert M. Avery is Assistant Director of the School of Chemical Engineering and Materials Science at the University of Oklahoma. He holds BS and MS degrees in Chemical Engineering from OU. For several years he was associated with IBM as a systems engineer on Shell Oil Account in Houston, Texas, before assuming his present position at OU in 1968.

Why should we in the College of Engineering be interested in the scientific development of Negro and Indian High School students?

The most obvious reason is that the minority groups represent an untapped source of students not only for engineering but for all the sciences. Surveys conducted by the engineering societies have indicated that the number of Negro and Indian engineers and scientists is far less than would be expected from either the size of the population or the number of college graduates. In other words, many of these students' capabilities are not being developed properly.

Secondly, as part of an institution of higher learning we should represent the more progressive element of our society; therefore, it is our responsibility to be at the forefront not only academically and professionally, but also socially. If one considers the minority groups' role in engineering and science, one should come to the conclusion that their future participation can do nothing but expand until they have filled the present vacuum. My question is "Why should we eat the dust of others already moving in this direction of progress?" "Why shouldn't we, and why can't we, lead the way in this area of human development?" Before I leave this stream of thought, I should like to point out that we are actually depriving our white engineering students of an opportunity of learning and understanding minority group people and their problems.

Dr. Hollomon, President of the University of Oklahoma, has told us several times that we should plan our programs to react to the needs of the state; that we should use our knowledge to help solve the human and social problems of our time; and that we must work together and be interested in the University as a whole. There are few better ways for us to work together as a college or university than to apply our knowledge to upgrade minority group students in science and mathematics. In addition, no one can deny that a definite need of our state is to develop the potential of our minority groups so they are in a position to help themselves as well as the state in the forms of tax revenue, leadership, and racial harmony.

Helping educationally deprived students realize their educational capabilities is one way we can do our part to help relieve some of the racial strife in our nation.

At this point I would like to explain how the School of Chemical Engineering and Materials Science got so involved in this problem. In April of 1968 three things occurred concurrently.

- An AIChE task force report on career guidance was received that pointed out that the number of Negro engineers and scientist was very small. Also, there are two urgent reasons to interest Negro students in engineering: The general need for engineers, and the need to correct a social situation of national importance.
- Dr. Hollomon, then president designate of OU, talked to the entire engineering faculty and in that talk urged us to turn out knowledge and skills to solving social and human problems in this state and across America.
- An article by Zelbert Moore and Paul Galloway, "Those You Never Know", appeared in an edition of *The Sooner* magazine that was dedicated to the plight of the Negro student at the University of Oklahoma.

As a result of these three events I was prompted to ask during a CEMS faculty discussion of our high school recruiting program, "Why don't we recruit black students?"

. . . We should represent the more progressive element of our society . . . Dr. Hollomon, President of the University of Oklahoma, has told us that we should use our knowledge to help solve . . . human and social problems . . .

Utilizing the AIChE task force report, numerous discussions with NAACP, Urban League, Oklahomans for Indian Opportunity, Negro principals and high school teachers, faculty members of OU and UCLA, and fellow Black graduate students, I came up with three basic problems:

- Lack of knowledge on the part of minority group high school teachers and students of the opportunities available in engineering.
- Even if these opportunities were understood, the great majority of students have inadequate background in mathematics and science to pursue engineering studies.
- Improper motivation from the home of the student.

Believing that there is a great source of capable engineers and scientists within the Negro and Indian communities, we in Chemical Engineering and Materials Science sponsored an Engineering Conference "Engineering Opportunities for Negro and Indian Youth" for Oklahoma high school principals, superintendents, science teachers, and counselors on September 27 and 28 at the University of Oklahoma.

ENGINEERING CONFERENCE

The program that involved 30 high school people, Negro and Indian students, Engineering faculty members, and specialities in the field of Science Education was designed around one central objective. That objective was to determine as best we could the barriers that exist for Negro and Indian youth in terms of their progress toward science oriented careers and possibly determine some ways of cracking those barriers. The first part of the session was a series of speakers presenting information in a variety of areas from Federal Education Programs to innovative experiments being conducted at UCLA. The purpose of these presentations was to provide participants will as much current information as possible concerning all areas that involve educationally disadvantaged.

The second part of the session was the real heart of the program and would determine the success or failure of the Conference. The participants were divided into discussion groups consisting of three to four high school participants, one Negro or Indian student, one of the Conference speakers, and an OU faculty member. These groups, under the direction of Engineering faculty members, utilized the knowledge acquired in the first part of the session and their own experiences to determine possible solutions to the following problems:

1. How to best communicate to students the opportunities in engineering?
2. How to determine which students are qualified for a career in engineering?
3. How the University may help to better prepare the student for engineering study?
4. The need for a relationship between the student and the University community.
5. The difficulty of freshman curriculum.

These along with many other problems were discussed and as a result we hope to obtain enough information to allow us to implement some constructive practical programs that will work over a long period of time.

CONFERENCE RESULTS

We are presently analyzing the various ideas generated by the Conference and therefore are not in a position to justify the rightness or the wrongness of the following suggestions.

HOW TO BEST COMMUNICATE TO STUDENTS THE OPPORTUNITIES IN ENGINEERING ?

- There should be high school visitations by engineering faculty members and whenever possible they should be accompanied by an engineering student who belongs to the same ethnic group as the high school students.
- A film should be made that would show the Negro and Indian engineering student in various classroom, laboratory, and social activities. The film should be one the student could identify with and say to himself, "If that student can do it, so can I."
- A summer program designed to acquaint the high-school science teachers with engineering. Also, introduce introductory courses in engineering at high school level which might be taught by engineers from industry or the university.
- Industry and government should implement programs for high school teachers and students that would give them a first hand look at engineering.
- All of these programs should start with seventh and eighth graders, and because of the generally low economic status of the minority groups, the financial or materialistic rewards should be emphasized; however, the professional status and pride of accomplishment should not be overlooked.

There are few better ways for us to work together . . . than to apply our knowledge to upgrade minority group students in science and mathematics . . .

• Finally, we need a method of demonstrating or giving evidence to Negro and Indian students that jobs and opportunities really do exist within industry.

HOW TO DETERMINE WHICH STUDENTS ARE QUALIFIED FOR A CAREER IN ENGINEERING ?

• We must curtail the "creaming" process of applying a selectivity procedure for admission to the University that eliminates 90% of the Negro and Indian students. This involves tests that measure white middle class values, inadequate counseling, and so on. The ACT should be reexamined to determine its validity for deprived groups. Special counseling and guidance is needed.

HOW THE UNIVERSITY MAY HELP TO BETTER PREPARE THE STUDENT FOR ENGINEERING STUDIES ?

• Coordinate and conduct summer sessions involving the best mathematics and science educators throughout the state and bring them together with the students who have had low quality instruction in these areas. This should occur every summer from the seventh grade through college. Because many of these students must work in the summer to put clothes on their backs we must not only pay all expenses but also reimburse them for the money they would have made had they worked instead of attending the summer session.

• Send university students into high schools as junior counselors. In many cases, the educationally disadvantaged student may communicate better with a college student nearer his age and with his same cultural background.

• There must be a university commitment on the part of the president, deans, and faculty members to support specialized programs.

a) Reserve 10% of admissions for students that cannot meet the usual requirements.
b) These students should have special counseling and programs such as a year pre-engineering on a pass-fail basis.
c) Tuition should be cancelled for any student from a family that makes less than $5,000 a year.
d) Scholarships that would provide full support for all undergraduate years. The Negro and Indian student is often affected by problems and situations that white students take in stride. The additional burden of supporting themselves is more than most students can handle.
e) Support of minority group instructors and graduate assistants. We can't afford to apply the usual criteria used for hiring faculty. Instead, we must ask the question "can they do the job that needs to be done?"
f) Establish science centers about the state where students and secondary school teachers could come for help and additional training. These could be manned by graduate assistants, part time instructors, interested faculty.

THE NEED FOR A RELATIONSHIP BETWEEN THE STUDENT AND THE UNIVERSITY COMMUNITY.

• There is a genuine feeling among the non-white students that the university system is geared to the white-student, his background, his social elevation, his values. The non-white are treated uniformily the same, but not equally.

• We need more representation of non-whites in administrative and faculty positions. Faculty needs to be more tolerant and understanding concerning cultural differences. We need an environment that supports and encourages students in their endeavor to establish values that are best for them.

• A "social awareness" program should be implemented in Engineering colleges. This would be an effort to involve students and faculty in social programs in the community.

DIFFICULTY OF FRESHMAN CURRICULUM.

• An effective system of tutorial instruction would not only aid the new student in course work, but might create a feeling of belonging. The tutorial sessions must be taken to the student in his dorm or places of residence. This might be a very worth while project for the various engineering clubs.

• Specialized counseling by concerned individuals is a must.

In general we concluded, for any program that proposes to work and produce practical results we must have from those involved an intense interest and an almost zealous commitment. We must not be overly skeptical of new and traditionally unacceptable modes of operation. We must be willing to accept the challenge of supporting broad comprehensive programs which may involve and affect all areas of university life. We must develop the flexibility to accept the different cultural values possessed by the non-white students.

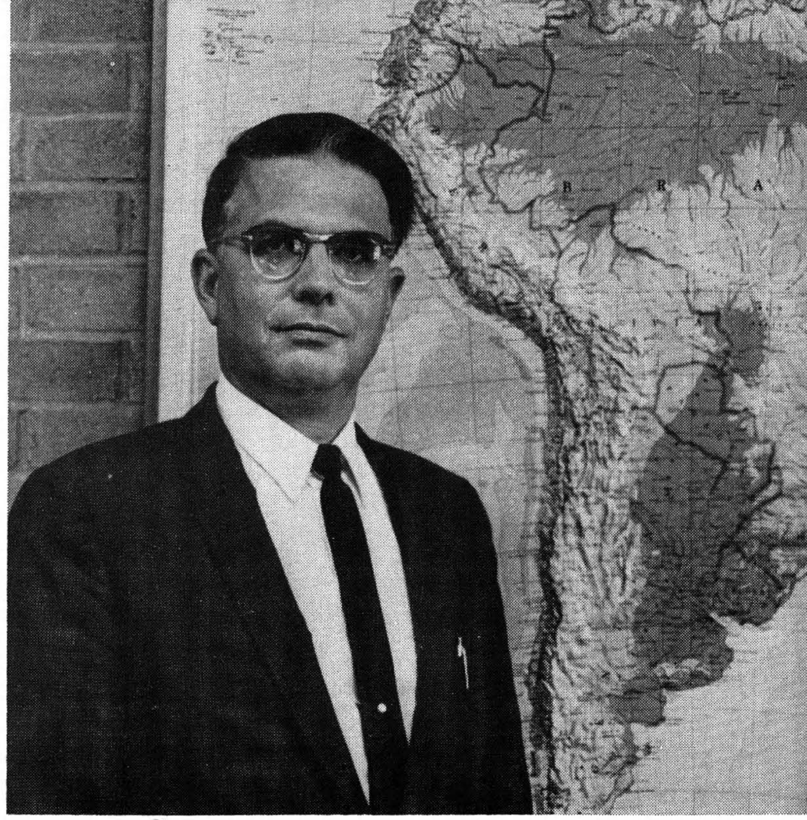
Any programs that are proposed should at least include the following:

1) Emphasis on the dignity of the individual.
2) Produce massive system changes.
3) Have built in incentives and guarantees for the young people who would participate.
4) Must include all educationally disadvantaged—Red, Black, White, Brown, Yellow and combinations thereof.

I think we in Chemical Engineering and Materials Science at the University of Oklahoma have made the commitment. Will you not join us?

Challenges for

THE UNIVERSITY IN INTERNATIONAL AFFAIRS



FRANK M. TILLER

Frank M. Tiller, M. D. Anderson professor of Chemical Engineering and Director of International Affairs obtained his bachelor's degree from the University of Louisville in 1937 and his PhD from the University of Cincinnati in 1946. In 1962 he was awarded a Doutor Honoris Causa by the University of Brazil. He has been a staff member at Cincinnati, Vanderbilt, Lamar Tech, and the Instituto de Oleos in Rio de Janeiro. As consultant, adviser and coordinator, his services have been rendered through a variety of organizations including the Fulbright Commission, Organization of American States, and Agency for International Development. Tiller has received a number of awards for articles appearing in AIChE publications.

In accepting world leadership, the United States has assumed vast and unfamiliar responsibilities over a remarkably short period of time. A mere twenty-five years separate U. S. military involvement in Viet Nam from the Neutrality Act which in 1939 forbade U. S. shipping from entering dangerous waters. A truly incredible change in atttitude has emerged as traditional isolationism has slowly faded from the contemporary scene.

Many people nurse a nostalgic hope that the world will return to a simpler time, that the U. S. can wash its hands of worrisome problems in remote lands. But these problems will not disappear, and the U. S. cannot cease being concerned with them. Headlines and taxes will continue to remind the nation's citizens that foreign affairs are an integral part of their lives.

In a democratic society, foreign policy depends upon decision-makers educated and trained in the common society with their actions being passed upon ultimately by the electorate. Thus the effectiveness of democratic government in foreign policy is limited by the quality of education as well as the traditions and dedication of both its citizens and its leaders. Without a sound education and understanding of world affairs, neither elected officials nor the nation's citizenry can expect to act intelligently in the critical international arena.

While the heavy burden of policy-making continues to be the responsibility of government, private citizens are becoming involved in international affairs on an increasing scale. In the earlier days of technical assistance, the government generally took direct responsibility for foreigh programs and frequently employed temporary consultants for guidance. Although technical experts mobilized for short-term junkets can provide valuable service, experience has shown that a variety of problems of underdeveloped countries do not yield to such efforts. Fire-fighting methods do not provide the careful planning and sustained supervision that many technical assistance programs require. Therefore, there has been a trend in recent years to enlist non-governmental organizations to carry out long-range foreign programs on a contract basis, an arrangement which represents an attractive alternative to the use of temporary consultants and diplomatic personnel serving short terms at their posts. Private citizens in organizations with contractual obligations find themselves intimately involved in the implementation of United States foreign policy.

In many parts of the world, a shortage of well-trained people rather than lack of capital is the major obstacle to progress. Educational programs are an essential factor in breaking the manpower bottleneck which impedes self-sustained economic development. Since educational programs are necessarily long-range in nature, continuity and experienced leadership are essential. U. S. universities like the University of Houston are uniquely equipped to provide such leadership.

All this suggests three challenges which confront American universities. The first is to train experts in international affairs. The second is to instill in the coming generations of citizens and community leaders a basic understanding of the importance and complexity of world affairs so that they not only will be able to review intelligently policies of the government but also will be better prepared to take a personal part in foreign activity if called upon. The third is for the university itself to take an active part in foreign programs under both governmental and private sponsorship.

CHEMICAL ENGINEERING DIVISION

Members of the ChE Division are reminded that the closing date for nominations for the sixth annual ChE Division 1969 Lectureship award is February 15, 1969. Nomination forms may be obtained from Dr. George Burnet, ChE Department, Iowa State University, Ames, Iowa, 50010. The award is sponsored by the Minnesota Mining and Manufacturing Company.

ASEE DIVISION ACTIVITIES

ASEE Annual Meeting, 23-26 June 1969, Pennsylvania State University. Chemical Engineering Division Program will consider educational aspects of selected interactions between chemical engineering and important social problems: 1. Health Problems, 2. New Energy Sources, 3. Urban Affairs. For further details, contact Chemical Engineering Division Program Chairman, K. B. Bischoff, Department of Chemical Engineering, University of Maryland, College Park, Maryland 20742.

ChE book reviews

Unit Operations of Chemical Engineering, 2nd Ed., W. L. McCabe and J. C. Smith.
McGraw-Hill Book Company, Inc. (1967),
pp viii + 1007, $15.50 .

The second edition of this book, like the first, is an undergraduate treatment of unit operations. It is divided into five sections: Introduction, Fuid Mechanics, Heat Transfer and Its Applications, Mass Transfer and Its Applications, and Operations Involving Particulate Solids. Section 1 (Introduction) contains one chapter which consists of a brief presentation of the basic laws and concepts needed for the understanding and mastery of the material to follow. Section 2 (Fluid Mechanics) contains eight chapters covering fluid statics, the flow of fluids through conduits and past immersed objects, pumping and metering of fluids, and agitation and mixing of liquids. Both incompressible and compressible fluids are treated and some material on non-Newtonian fluids is included. Section 3 (Heat Transfer and Its Applications) contains seven chapters covering conduction, convection, radiation, heat exchangers, and evaporation. Section 4 (Mass Transfer and Its Applications) consists of eight chapters covering phase equilibria, distillation, diffusion, absorption, humidification, leaching and extraction, and crystallization. Section 5 (Operations Involving Particulate Solids) contains five chapters covering properties and handling of solids, size reduction, mixing, mechanical separations, and drying.

Throughout the book, the treatment of equipment and theory is well balanced and many example problems illustrating the principles and theory set forth are included. In addition, most chapters contain a number of excellent problems for which a solution manual is available from the publisher.

Those familiar with the first edition will find a number of changes incorporated in this edition. Most of the long chapters in the first edition have been broken down into a number of shorter chapters in the present edition and the material considerably rearranged and updated by the inclusion of material from transport phenomena.

The book is well written and relatively free from errors. It is highly recommended.

HENDERSON C. WARD
Georgia Institute of Technology

FLOW and TRANSFER at FLUID INTERFACES*
Part II - Models

L. E. SCRIVEN
University of Minnesota
Minneapolis, Minn.

In the opening part of the lecture I reviewed the evolution of chemical engineering thought about mechanisms of transfer between fluid phases. I attempted to identify various stages of the development and went so far as to try to draw some lessons from the historical record as I perceive it. The lessons I offered seem to me to contradict the viewpoint from which the loudest attacks on fundamental chemical engineering are launched. Now let us turn again to the goal of understanding flow and transfer at fluid interfaces.

WE SET THE STAGE by recalling the contrast between boundary conditions on incompressible flow at rigid walls and at free surfaces. At a solid surface all relative velocity vanishes; it follows that the normal and tangential parts of the nearby velocity field are given

$$v_n \simeq -\frac{\lambda^2}{2}\nabla_{II}\cdot\left(\frac{\partial \underset{\sim}{v}_{II}}{\partial\lambda}\right)_{\lambda=0} \qquad \underset{\sim}{v}_{II} \simeq \lambda\left(\frac{\partial \underset{\sim}{v}_{II}}{\partial\lambda}\right)_{\lambda=0}$$

where λ is the perpendicular distance from the solid. . . . At a free interface it is the tangential part of viscous traction that vanishes; consequently the relative velocity nearby consists of

$$v_n - v_n|_0 \simeq \lambda(2H\, v_n|_0 - \nabla_{II}\cdot \underset{\sim}{v}_{II}|_0) \qquad \underset{\sim}{v}_{II} - \underset{\sim}{v}_{II}|_0 \simeq \lambda(H\, \underset{\sim}{v}_{II}|_0 + \nabla_{II}\, v_n|_0)$$

where H is the local mean curvature of the interface. . . . The most important point to make here is that near a free interface the rate of convection away from or toward it is *directly proportional* to the distance from it — just as in the stagnation flow featured below — and the proportionality factor is the rate of interface dilation by both "surface inflation" and "surface stretch". Now it is clear from the expression for total convective and diffusive flux, vc-D∇c, together with the convection diffusion equation, that flow parallel or antiparallel to the direction of transfer has the greatest effect on transfer rate. What implications for interphase transfer can we draw from this fact?

There must obviously be transfer from elements of one fluid phase to elements of the second fluid phase. So regardless of the violence of convective movements executed by fluid elements, the ultimate mechanism of *interphase* transfer (at least as long as the motions remain continuous) must be by molecular diffusion. However, the molecular diffusion process can be and usually is strongly affected by convective motions. This is especially true in the vicinity of fluid interfaces, an important point that too often has been overlooked in the literature. The effect of convection on diffusion, as governed by the convective diffusion equation, will be one of my main themes.

That diffusion in some neighborhood of the interface is the *controlling* resistance to interphase transfer, is generally presumed and is indeed so in many laboratory and practical siutations. We will not discuss exceptions here.

The effect of convection on diffusion is certainly strong around a turbulently agitated interface. It is logical to ask where in the chaotic jumble of transitory local flows the effect is strongest (Figure 1). The question can be answered by dissecting the jumble into recognizable parts and then examining those parts in detail. In a paper before the Annual Meeting of the AIChE in 1964 Raymond W. C. Chan and I proposed that chaos can be resolved, to a fair approximation so far as convective diffusion is concerned, into mixed populations of relatively simple, practically laminar, small-scale flows which we call microflow elements (Figure 2). The lifetimes of these flows are related to timescales of the agitating turbulence, especially the intermittency of larger scale incursions on them; we will not, however, attempt here to discuss basic aspects of turbulence and its interactions

*Based on the main part of the 1968 Annual Lecture to the Chemical Engineering Division, ASEE at the University of California at Los Angeles June 18, 1968, sponsored by the 3M Company.

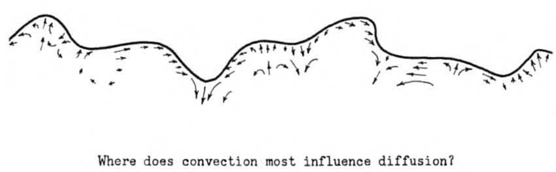


Fig. 1.—Populations of Microflow Elements.

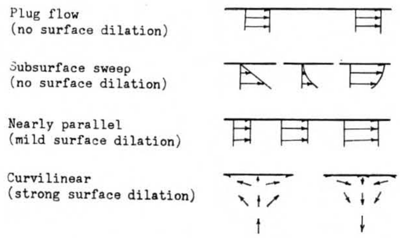


Fig. 2.—Some Basic Flows—"Microflow Elements."

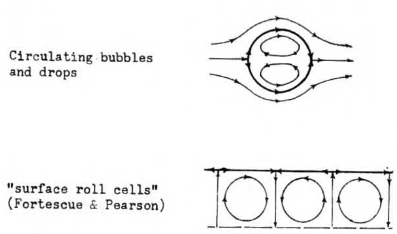


Fig. 3.—Some Composite Flows.

with fluid interfaces. For our purposes the basic types of surface flows should be classified according to rate of surface dilation and thus convvective influence on interphase transfer (Figure 2). We note that well-ordered flows as well as chaotic ones can be modeled by combinations of microflow elements (examples in Figure 3). More noteworthy, we find that we can rationalize existing transfer models (Figures 4 and 5 in which, for simplicity, the situation in the second phase is disregarded) and systematically point out alternatives to them (Figure 6).

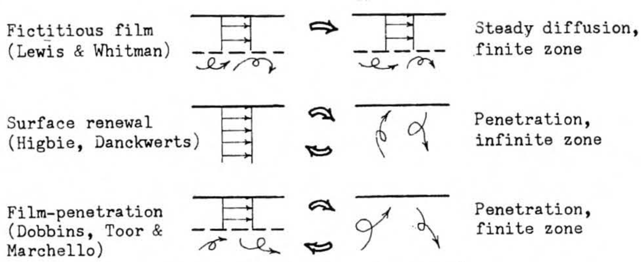


Fig. 4.—Standard Transfer Models.

The film model (Figure 4) corresponds in effect to a thin layer in steady plug-like flow along the interface and bathed beneath by fluid that is somehow kept completely mixed. All of the other models correspond to one or another local flow regime that is intermittently, suddenly and, in most cases, completely interrupted by turbulent action and then instantaneously reestablished with the participating fluid replaced to some extent (in Figures 4 - 6 the persistent regime is indicated on the left, the interruptive event on the right). It becomes clear that not one of the earlier models corresponds to a flow regime in which convection influences diffusion at all: this effect is represented only in the nature of the intermittent interruptions.

Chan and I argued that in the mixed population at a turbulent interface it is the flows displaying strong surface dilation (or contraction, of course) that most strongly influence diffusion; we suggested that the convective effect of these flows swamps all others; and we proposed that it can be modeled by a single population of steady, irrotational stagnation flows — at least on the liquid side of gas-liquid interfaces. These flows are the purest embodiment of the above formulas for relative velocity near an interface. More about them shortly.

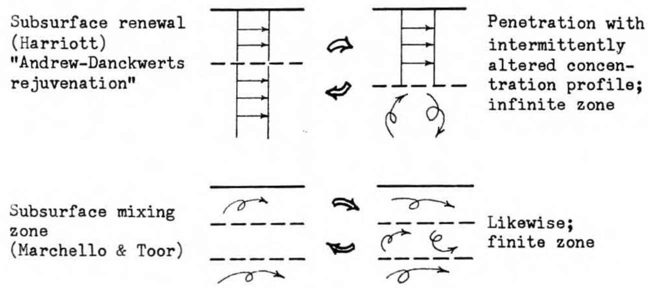


Fig. 5.—More Transfer Models

REGARDLESS OF THE MICROFLOW elements one favors in trying to understand interphase transfer, the first step is to solve the differential equation describing transport within the elements, and this requires that boundary conditions and, frequently, initial conditions be chosen. In all of the earlier models — film, penetration, and hybrids — these choices are the sole means of accounting for convective transport (regarded as convective mixing in some instances). As indicated in Figure 7, the differential equation has been that for pure diffusion. The correct equation is that for convective diffusion, in Figure 7 shown in somewhat simplified form, with a class of velocity fields characterized by a parameter a. The appropriate boundary and initial conditions may depend upon relative magnitudes of a penetration depth for convective dif-

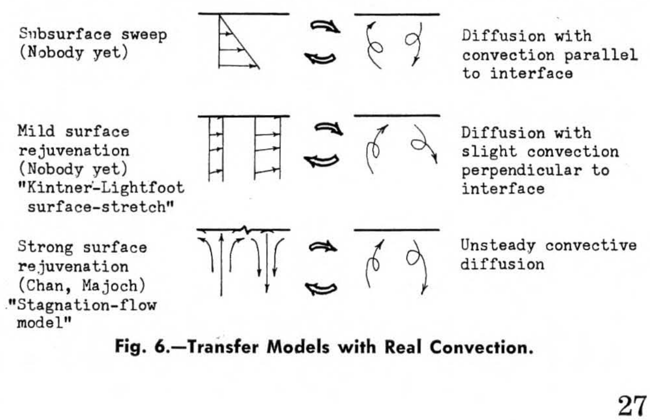


Fig. 6.—Transfer Models with Real Convection.

Mathematics of Model Elements

Film and penetration:	$\frac{\partial c}{\partial t} = \mathcal{D}\frac{\partial^2 c}{\partial z^2}$, $\left.\begin{matrix} c(z,0) \\ c(0,t) \\ c(L,t) \end{matrix}\right\}$	chosen to represent flow somehow
Convective diffusion:	$\frac{\partial c}{\partial t} + \underset{\sim}{v} \cdot \nabla c = \mathcal{D}\nabla^2 c$, $\underset{\sim}{v}(\underset{\sim}{x}, t; a)$	representing flow
Solution:	$j[t; c(z,0), L, a] = -\mathcal{D}\,\partial c/\partial z$	instantaneous flux

Fig. 7.—Mathematics of Model Elements.

fusion, *not* pure diffusion, and a hydrodynamic depth scale, all usually related to turbulence properties beyond our present scope. In any case, the differential equation system is solved for the instantaneous flux across the interface, which remains a function of the age of the microflow element, of the parameter(s) characterizing flow within it, and of any parameters in the initial and boundary conditions (for example, the depth at which concentration is supposed to remain constant in film-type models: L in Figure 7).

The second step, in cases of chaotically agitated interfaces, is to calculate the surface-area-average flux over the population (or populations) of currently existing microflow elements, each of which occupies some small patch in the surface mosaic. As indicated in Figure 8, the procedure

Instantaneous average flux over area	$\bar{j} = \frac{1}{A}\iint j[t(dA); \ldots L(dA), a(dA)]dA$
Distribution function, e.g. surface-element ages	$\psi(t;\tau) \equiv \frac{\delta A(t)}{A\delta t(\delta A)}$, $\int_0^\infty \psi\, dt = 1$
Average flux (assumed stationary in time)	$\bar{j}(\tau) = \int_0^\infty j(t)\psi(t;\tau)dt$

Fig. 8.—Mathematics of Populations of Elements

is to introduce (for each population) a distribution of fractional surface area over age of the microflow elements and over the quantities that characterize flow and transfer in them. Integration over age and these quantities completes the calculation if the gross regime is stationary in time, the result being a formula for time-and-surface-area-average flux in terms of the parameters that appear in the distribution function — for example, the mean lifetime of a microflow element, or the rate of "renewal" of microflow elements. Ideally the distribution function would be chosen for its fidelity to real populations of microflow elements. Unfortunately little is known about the latter. On the other hand, Hanratty (1956) and others since have noticed that a final formula for average flux is insensitive to some changes in the distribution function on which it is based. Writers on interphase transfer have identified distribution functions in tables of integral transforms, papers on residence time distributions, and elsewhere and have selected functions to work with chiefly for their mathematical tractability. With one exception they have been one-variable distribution functions, the variable being surface lifetime, which stands unambigously for lifetime of an element provided there is no surface dilation. The convenient $\psi = s\exp(-st)$ of Danckwert's pioneering 1951 paper is a familiar example (recall that s is both the fractional rate of replacement of elements and the reciprocal of the mean lifetime).

The one published exception is the two-variable distribution function in Harriott's noteworthy 1962 paper. The two variables are dictated by the microflow model and are element lifetime and thickness of the plugflow zone (see upper diagram in Figure 5). Harriott took the joint function to be a product of two single-variable functions, namely the familiar exponential distribution of lifetimes and the slightly more general gamma distribution of thicknesses (cf. Figure 9). Actually Harriott's microflow element is more complicated than anything we have discussed because it is only partially replaced in each interruptive event and consequently remembers something of its past. This non-Markovian feature together with the two-variable distribution function evidently forced a monumental Monte Carlo style calculation of transient approach to the statistically stationary transfer regime.

Another exception is the two-variable distribution function demanded by steady, irrotational stagnation flow elements that Chan analyzed and my current collaborator L. V. Majoch has considered further. The variables are element age t and stagnation flow strength a. In the absence of contraindications the simplest hypothesis is once again that the joint function is the product of two independent single-variable functions (cf. Figure 9).

Populations Distributed Over Two Parameters

$$\bar{j}(\tau,\Lambda) = \int_0^\infty\int_0^\infty j(t;L)\psi(t)\phi(L)dL\,dt, \qquad \text{(Harriott, in effect)}$$

$$\bar{j}(\tau,\alpha) = \int_0^\infty\int_{-\infty}^\infty j(t;a)\psi(t)\phi(a)da\,dt, \qquad \text{Chan, Majoch}$$

Fig. 9.—Populations Distributed Over Two Parameters.

If and when a single type of microflow element does not dominate the transfer situation — or does not lead to a desired functional form of average flux — one can turn to mixed populations of different types of elements. Danckwerts noted the possibility in his 1951 paper. The example in Figure 10 corresponds to two populations of the sort made especially convenient by tables of Laplace transforms; the two are distinguished by different mean element lifetimes ($\tau_1 = 1/s_1$, $\tau_2 = 1/s_2$).

$$\bar{j}(\tau_i, p_i) = \Sigma p_i \int_0^\infty j_i(t)\psi_i(t;\tau_i)dt, \quad \Sigma p_i = 1$$

$$\text{Example:} \quad \bar{j}(\tau_1, \tau_2, p) = p\int_0^\infty j_1(t)e^{-t/\tau_1}\, d(t/\tau_1) + (1-p)\int_0^\infty j_2(t)e^{-t/\tau_2}\, d(t/\tau_2)$$

Fig. 10.—Mixed Populations.

At this point I have sketched a crude but serviceable conception of turbulent fluid interfaces, which I believe is more detailed and realistic — and pedagogically attractive — than any available heretofore, and I have delineated for the first time the general strategy for modeling turbulent action by means of populations of microflow elements. This strategy should work equally well, incidentally, in treating some turbulent reaction systems, for instance. So far as flow and transfer are concerned, the strategy suffers from the lack of experimental data on the population dynamics of local flows at chaotically agitated fluid interfaces. Just as importantly, it suffers from the lack of development of mathematical models of microflow elements with "real convection." The remainder of the lecture is devoted to the latter, that is, to some relevant solutions of the convective diffusion equation.

EDITOR'S NOTE: The remainder of the lecture will be published in the Spring Issue of CEE.

SELECTED REFERENCES

Angelo, J. B., Lightfoot, E. N., and Howard, D. W., *AIChE J.* 12, 751-760 (1966).

Byers, C. H., and King, C. J., *AIChE J.* 13, 628-644 (1967).

Chan, W. C., "Transfer across flowing interfaces: stagnation-flow models," Parts B, C, F of Ph.D Dissertation, Univ. of Minn., 1964.

Chan, W. C., and Scriven, L. E., "Absorption into irritational stagnation flow: a case study of convective diffusion theory," MS. submitted to *I&EC* Funda.

Danckwerts, P. V., *I&EC* 43, 1460-1467 (1951).

Danckwerts, P. V., Kennedy, A. M., and Roberts, D., *Chem. Eng. Sci.* 18, 63-72 (1963).

Drew, T. B., *Trans. AIChE* 26, 26-80 (1931).

Harriott, P., *Chem. Eng. Sci.* 17, 149-154 (1962).

Higbie, R. W., *Trans. AIChE* 31, 365-389 (1935).

King, C. J., *I&EC Funda.* 5, 1-8 (1966).

Kishinevskii, M. Kh., *Zh. Priklad. Khim.* 27, 382-390 (1954). AERE translation available from Special Libraries Association.

Kishinevskii, M. Kh., and Pamfilov, A. V., *Zh. Priklad. Khim.* 22, 1173-1182 (1949).

Koppel, L. B., Patel, R. D., and Holmes, J. T., *AIChE J.* 12, 941-955 (1966).

Langmuir, I., Collected Works of Irving Langmuir, Vol. 2, Part 1, Pergamon Press, London 1960.

Levich, V. G., Physicochemical Hydrodynamics, Prentice-Hall, Inc., Englewood Cliffs 1962.

Perlmutter, D. D., *Chem. Eng. Sci.* 16, 287-296 (1961).

Ruckenstein, E. and Berbente, C. P., *AIChE J.* 13, 1205-1207 (1967).

Scriven, L. E., and Pigford, R. L., *AIChE J.* 4, 382-10S (1958).

Scriven, L. E., and Pigford, R. L., *AIChE J.* 5, 397-402 (1959).

Spriggs, T. W., Grgurich, D. A., and Scriven, L. E., "Interaction of circular vortices with mobile interfaces: a physical model of surface renewal," MS. to be submitted to *AIChE J.*

Walker, W. H., Lewis, W. K., and McAdams, W. H., Principles of Chemical Engineering, McGraw-Hill, New York (1st ed. 1923, 2nd ed. 1927, 3rd ed. 1937).

LETTERS (Continued from page 5)

Editor:

The Spring 1968 issue of CEE was very interesting. I am particularly glad to see evidence of a forum for opinions like those of Lenz (Industry Needs Scientific Engineers Not Engineering Scientists).

During my several years as teacher and department chairman, I felt chemical engineering educators in ASEE were talking only to themselves in a positive feedback situation leading to a runaway reaction on teaching engineering science. Lenz's points are very valid from my experience in industry in research and now in operations, and from the statements of colleagues and competitors. The quotes from Fulton and Souders present points that all teachers should ponder.

Perhaps recitation of a coalescence of some recent experiences in recruiting will help teachers comprehend what a number of industrialists are trying to say. Fundamentals seem to be taught as an end unto themselves, not as tools to be used in the true engineering sense, because most of the teachers' time, research and study are focused on fundamental phenomena. Unfortunately the student lacks the experience to differentiate between the teacher's environment and the things that really need to be done in industry. Consquently, the new graduate is unprepared to face the situation when he learns that the very important problems of industry and society are usually interdisciplinary. Too frequently he retreats from situations offering real opportunity for growth and prosperity to the security of organizations with large sections of people working in the same discipline. It is truly a shame that

Letters (Continued on page 44)

THE ANSWERS TO YOUR

FUEL CELLS

John O'M. Bockris, University of Pennsylvania, and **S. Srinivasan,** State University of New York, Downstate Medical Center. Available Spring

Sets forth the theoretical basis of electrochemical energy conversion. Unlike other books, this work considers the basic electrode kinetics of the fuel cell.

HEAT TRANSFER, Second Edition

Jack P. Holman, Southern Methodist University. 432 pages, $10.50

Revision of a standard text for undergraduate courses. Contains new material on thermal contact conductance, radiation network analysis, conduction shape factors, an analytical model for liquid metal heat transfer, and many other topics.

THERMODYNAMICS

Jack P. Holman, Southern Methodist University. Available Spring

Offers a brief, broad coverage of **all** aspects of thermodynamics for undergraduate introductory courses. The emphasis is on simplicity, clarity, and teachability, and the coverage includes both macroscopic and microscopic thermodynamics with an introduction to transport gases. Conventional power cycle applications and introductory material on direct energy conversion schemes are also presented.

ENGINEERING DIFFERENTIAL SYSTEMS

Robert D. Kersten, Florida Technological University. Available Spring

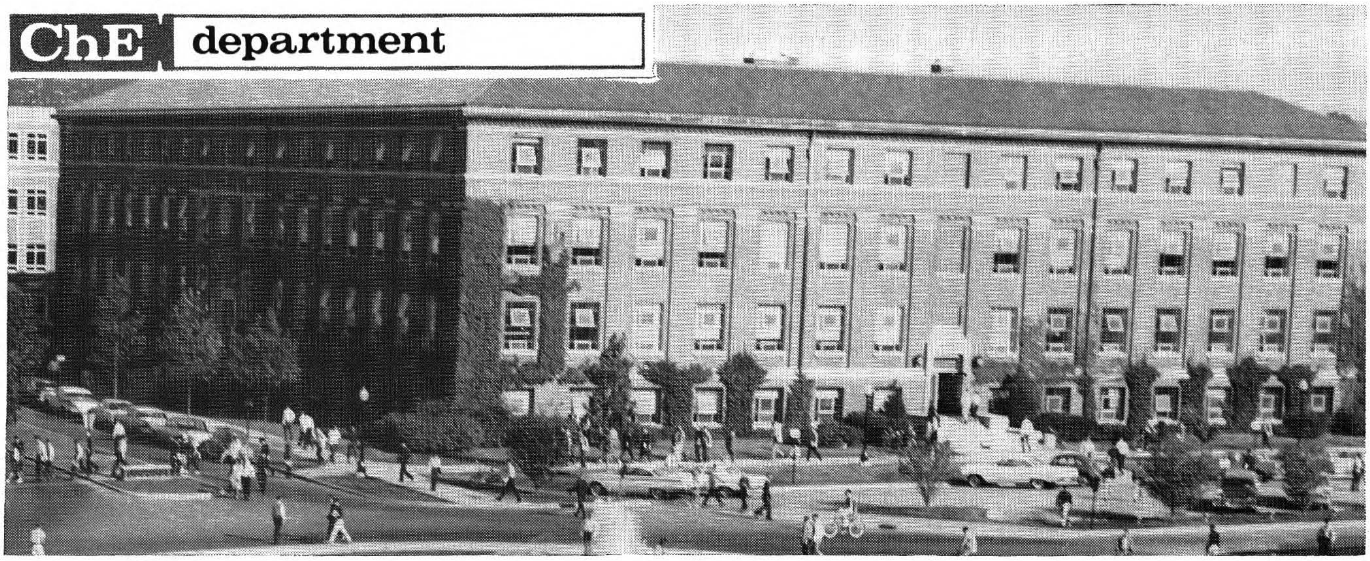
The first book of its kind to treat both analytical methods in engineering — the classical continuous approach and the "discrete" approach usually associated with numerical methods. It proceeds from the typical cases, which can be mathematically treated by the classical approach, to the more difficult cases, which must be handled by some numerical technique.

MASS TRANSFER OPERATIONS, Second Edition

Robert E. Treybal, New York University. **McGraw-Hill Series in Chemical Engineering.** 688 pages, $15.75

Provides a vehicle for teaching the characteristics, principles, and techniques of design of equipment for mass transfer operations. Theoretical principles are applied to the practical problems of equipment design.

ChE department



HAIL PURDUE!

CEE features a large state university that emphasizes both undergraduate and graduate education.

ROBERT A. GREENKORN, *Chairman*

"All that professors worry about is research and pubilcation."

"PROFESSORS SPEND TOO MUCH TIME IN CLASS."

"Students don't even know what a reboiler looks like!"

"Chemical engineers do not have enough mathmatics to keep up with other engineers."

"I NEVER HAD DIFFERENTIAL EQUATIONS — WHY DO STUDENTS NEED THEM NOW?"

"Economics is important; engineering is using money."

"Engineering is science."

"WE MUST HAVE DISTINCT DISCIPLINES!"

"Core programs are best."

And so it goes. When one collects a week's worth of comments from colleagues, students, industrial visitors, professors from other departments and other universities, and the man on the street, the sum equals quandary.

HOW DO YOU EDUCATE A CHEMICAL ENGINEER ?

What is the best way for a professional school to educate a young man or woman to become a chemical engineer? Obviously, there is disagreement among the people involved and opinions continually change. To use current jargon, we must try to optimize the situation. What follows outlines briefly our approach at Purdue and, though we are sure it is not a stationary point, we believe it is a sound intermediate one.

We believe the major educational problem facing us is to prepare students not only for immediate entry into professional activity but for remaining effective in a rapidly advancing technological community. We believe students must be given an education solidly rooted in the fundamentals of science and engineering rather than a mere capability for manipulating current methods. To make certain they are capable of extending their scientific and engineering knowledge throughout their careers, they must be taught how to appy fundamentals to new problems.

Students must associate with teachers who are themselves students, engaged in day-to-day learning through scholarly activity. This requires a strong commitment of the faculty to individual and cooperative research, so the excitement of discovery and learning can cascade from individual professors into the graduate and undergraduate programs. We agree with those who believe it is not desirable, nor probably even possible, to separate research and teaching and still maintain the scholarly atmosphere necessary to prepare students for today's technology.

Students must associate with teachers who are themselves students, engaged in day-to-day learning through scholarly activity.

RESEARCH INTERESTS ARE VARIED

Our faculty's research interests cover the areas of adaptive control, equilibrium properties of mixtures (both gas and liquid), surface reaction mechanisms of catalysis, transport in dispersed systems, rheologic and fluid flow studies with special emphasis on pulsatile flow and unsteady state systems, mathematical modeling and experimental analysis of process kinetics, and the physical and chemical characteristics of multicomponent systems.

Currently, for example, one of our staff members is forming a series of algorithms for the control of distributed systems; another is measuring partial volume at infinite dilution to determine the component properties of mixtures; a group is studying the meaning of the dispersion tensor in non-uniform, anisotropic porous media. A special laboratory is being built by one of our faculty for measuring the surface properties of catalysts. A few other examples of current research are: the effect of reactor surface on process kinetics; application of hybrid computer for chemical process simulation; the study of heat transfer to bubbles rising in fluidized beds.

In our research efforts we are loosely organized on a group basis so that professors who have a common interest may share projects, and, in addition, carry out their own individual research.

For example, we have a group collectively studying transport in dispersed systems. It happens that much of the mathematics and statistical modeling for individual studies in this area—those for porous media, dispersion of drops, and fluidization of solid particles—have a common base; here we work together. We go on from there to work individually. The result is a saving of time, sharing of experience, more efficient use of equipment—and, we think, a broadening of the experience open to students. The value of the system—for both students and faculty—is also amplified by the ability to have group seminars which become more workable because of the sharing experience.

Graduate studies are not simply a continuation of the scheme of undergraduate education at a more advanced level, such as might be achieved by a prescribed curriculum of advanced courses. Rather, each student works out his own program of self-education to meet his own special interests and needs. Apart from the student's efforts to become professionally competent, he seeks to develop and utilize his own intellectual and creative power and thus make his maximum contribution to society.

We are fortunate that the nine schools and departments in the Schools of Engineering at Purdue have the opportunity to engage in interdisciplinary research with each other and with several special organizations such as the thermophysical properties research center, the laboratory for applied industrial control, the jet propulsion center and the bioengineering group. Thus, our faculty and students are exposed to a broad category of facilities and problems.

UNDERGRADUATE PROGRAM IS IN SEQUENCES

We have organized the chemical engineering part of the undergraduate program into five sequences: transport; thermodynamics and kinetics; control; design, computer applications, and optimization; and electives. We are fortunate that our senior class usually numbers about 100, enabling us to offer a series of elective courses designed either to prepare students for graduate school or for more intensive study of topics not fully covered in the normal sequences.

While we have adopted the transport approach to teaching physical operations, we have turned it around. We teach stage operations first, the transfer operations, then the physics of transport phenomena—the integral balances before the differential balances. We believe the student will get a better hold on the whole subject this way.

For our control sequence, we have a somewhat unusual laboratory which features several micro experiments, an all-purpose experiment, and analog computing equipment which may be used for adaptive control of these experiments.

We have broken our senior design sequence into two courses—the first of which emphasizes the modern mathematical tools of economics and optimization while the second course includes the strategy of design and three different types of computational sections from which the student may choose: one emphasizing computer simulation; another, the more classical approach to the design of several small processes; the third, a large case study brought in by an industrial practitioner.

We offer six elective courses—the students must take two. Three are aimed at graduate work; chemical equilibrium, applied chemical engineering mathematics, computer simulation. Three are more general; polymer science and engineering, statistical design and analysis, petroleum refinery engineering.

Our junior and senior laboratories are parts of definite course sequences. In this way, the theory and techniques the student learns in class are also studied physically in the laboratory. The students measure transport properties in the junior laboratory; the emphasis in the senior laboratory is on synthesis and application of students' knowledge to open-ended problems in chemical engineering.

Our students are taught how to use the computer as sophomores, and we are presently engaged in including computer applications in every undergraduate course. We have direct teletype input to the CDC 6500 and IBM 7094 so students can call programs at any time to calculate course problems.

Approximately one-fourth of our students participate in the Purdue Cooperative Engineering Education Program, spending alternate semesters in formal class work and in one of 44 industrial companies. The association with industry and actual problems is a very valuable addition to education. We find our co-op students appreciate the fundamental flavor of their academic work.

CHEMISTRY IS IMPORTANT

Chemistry, of course, is the distinguishing feature of a chemical engineering program, and competence in chemistry as well as physics and mathematics is the mark of a chemical engineer. Although we are often in the noisy minority concerning the role of chemistry in engineering, we firmly believe the difference is a necessary one. This tends to give us flexibility and identity as well as a spirit of independence from the remainder of engineering disciplines on campus. This attribute is of value in the performance of our job as liason between engineering and chemistry.

Looking back over these paragraphs and comparing them to the comments we have all heard, it is plain we are not "all things to all people." We have problems, certainly—of time, facilities, financing. These we live with and strive to change, as did our predecessors and as will those who follow us.

But we do believe scholarly activity and teaching at a university must go hand-in-hand. We do believe the best education is one based on science and engineering fundamentals. We are convinced we must show the student the best way to use these fundamentals and implant in him the desire to continue to learn throughout his professional career.

ChE views and opinions

ON THE RECRUITMENT OF CHEMICAL ENGINEERS

ERNEST J. HENLEY
University of Houston
Houston, Texas 77004

Professor Metcalfe in his excellent article "Where Are The Engineers" proposes that we reverse the trend of "declining acceptance of engineering as a course of study" by "stronger recruitment and greater retention of entering students."* This is a very popular viewpoint. The "grass roots" approach is strongly endorsed by the AIChE, as has been pointed out by Kuebe and Kovacs "More Chemical Engineers Necessary: A Problem in Career Guidance."**

Since past recruiting efforts have met with only very limited or, at best, local success, it seems appropriate to question the efficacy of this approach. (There may also be a question of ethics, but this is admittedly a highly debatable point.) Personally, I am unenthusiastic about recruiting activities because 1) in the long run, all competitive advertisement must be self-cancelling and 2) it has diverted our attention from the real problem; one does not find a cure for a disease by looking at the symptoms.

The average American engineering students of the forties and fifties were first-generation college students from 'blue collar' homes. The status of being an engineer and the attending salary were very meaningful to this "upward

* T. B. Metcalfe, CEE, 2, 142, (1968).

**W. R. Kube and W. L. Kovacs, CEP, 64, No. 68, 95 (1968).

Professor Henley urges:

- **Full implementation of ASEE Goals report, followed by the establishment of engineering graduate schools on a professional basis.**
- **More versatile undergraduate programs, designed to attract the sons and daughters of college graduates and to encourage newer graduate research areas.**
- **Stronger chemical engineering graduate programs in environmental, microelectronic, biomedical, or ocean engineering.**
- **AIChE disapproval of graduate work in deparftments that have less than thirty graduate students and ten faculty members.**
- **The requirement of one year of introductory undergraduate work in the U. S. before admission of foreign students to graduate school.**

mobile" segment of the population. It is my contention that one of the primary defects of our present engineering programs is that we are still attracting primarily this shrinking segment of the college population. We are failing to 'trade up.' We are not attracting the sons and daughters of college graduates. The engineering college at too many of our 'prestige' universities has become the campus stepchild.

As a group, we appear to be caught in a quagmire of reactionary thinking, and I fear that unless we take a few risks and make fundamental changes, our programs will not attract the type of students we want and industry needs. Unfortunately, too many of the students we have now in engineering have a clearly defined, bread-and-butter attitude toward their studies. *We need a few hippie types !*

As Professor Metcalfe clearly points out, the growth has moved away from the traditional engineering fields. Chemical engineering is losing its viability, and the situtaion is deteriorating, not improving. It is sad to note that the number of chemical engineering departments that have been able to make contributions to, or to mount significant programs in the newer fields such as environmental, microelectronic, biomedical, or oceanographic engineering is close to zero. What is even more deplorable is the large number of departments which have started programs in these areas and failed, or even worse, have inadequately staffed and funded programs. By and large, we have not succeeded in creating an environment in which new programs can become self-sustaining.

Having stated, in a general way, the malaise from which we suffer, I would like to briefly pinpoint some of the more serious illnesses in our current graduate and undergraduate programs and some of the things we can do to correct them. Most of these problems are cited and documented in the ASEE Goals Study whose critics have chosen to adopt an "I'm all right Jack" attitude even though it is abundantly clear that we are not attracting the type and numbers of students the industry needs.

- **Graduate Programs** — The majority of graduate programs are too small, too fragmented, and too undernourished to offer its too-few sturents an exciting educational experience, or the opportunity to do meaningful research. Too many of the student research projects produce information which is new to the student, but of questionable value to the skilled practitioner. The student knows this, and is discouraged by it. As a symptom of this situation, consider the desultory chemical engineering seminar as it exists at too many institutions; student participation is practically nil; the majority of the staff does not attend.

The bread-and-butter aspects that characterize undergraduate education at many schools has infiltrated a large number of the graduate schools. The situation is appreciably aggravated by the high percentage of foreign students at many schools. It is my contention that the majority of the Asian foreign students should be admitted to graduate school only after first completing one year of indoctrinary undergraduate work in the United States. The very large percentage of foreign students (greater than 20 percent) at some schools is unhealthy; they cannot be assimilated. A young professor from a university in Missouri told me that when he tried to recruit one of his own seniors for graduate school the boy turned to him and said, "Gee, Professor, I thought graduate school was only for foreign students!"

Many of the difficulties stemming from the lack of excitement and intellectual stimulation at many engineering schools could be surmounted by increased institutional specialization and a more general pooling of resources. A five man department with research specialties in fluid dynamics, control theory, air pollution, kinetics, and mass transfer probably has no viable program in any of these fields; a department with five men working on related catalysis problems

Our average graduate has had the benefit of neither a sound cultural nor a good scientific education. He is as ignorant of lasers and holography as he is of music and poetry.

should achieve a leading position in its field. (As a point of fact, I do not believe that the AIChE should permit graduate work in departments that have less than thirty graduate students and ten faculty members.)

We should also recognize that students who are taking three or four stiff courses cannot simultaneously do good research. We are making a rat race out of our graduate programs by overloading the students to the point where they have no time for outside reading or the pursuit of intellectual interests.

- **Undergraduate Programs** — Too often these represent academic straight jackets and, as such, are outmoded and rejected by the type of students we would like to have. Our average graduate has had the benefit of neither a sound cultural nor a good scientific education. He is as ignorant of lasers and holography as he is of music and poetry. His education lacks versatility.

The undergraduate students' lack of versatility is a major contributing factor to the inability of graduate engineering departments to move into new academic and research areas. Whether we like it or not, we are trapped in a cycle which has proven veritably impossible to break. It is very difficult to convince a chemical engineer graduate student to do research on anything except heat, mass, and momentum transfer, control, or kinetics.

I believe that many of the major problems discussed here can be alleviated by the full implementation of the Goals Report, followed by the establishment of engineering graduate schools on a professional basis. Michigan State's success in attracting an increased number of students following a major curriculum reform holds a lesson for all of us.* The recent liberalization of course requirements at Michigan, Northwestern, Minnesota, Ohio State, Pennsylvania, and Lehigh are salutory. Failure to make major changes in our programs and our approach to engineering education must result in a continuing erosion in the quality and quantity of students attracted into engineering in general and chemical engineering in particular.

*C & E News, Aug. 28, 59, (1968).

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ENGINEERING AND PUBLIC AFFAIRS

Directions for Education and Research

E. H. BLUM

(Continued from page 9)

DIRECTIONS OF RESEARCH

Even if engineers (and social scientists) were to agree in principle that they should consider social (and technical) objectives and consequences, most would not be likely actually to do so if they did not know how. Concomitantly, lacking a tradition that demands the larger perspective, most would not feel impelled to develop new methods and expand their field of view once they found that their current methods were inadequate. **One of the main reasons, or excuses, advanced by practitioners in the separate disciplines for not working in the joint area of engineering and public affairs is the lack of adequate methodology, and one of the main reasons advanced for not working on methodology is the lack of overt demand.**

We can break this circular deadlock either by developing methodology or by creating effective demand, e.g., by requiring better research on important questions. Because we now know little about multi-disciplinary research, methodology developed in a vacuum is likely to be sterile. The best methodology, we might surmise, will ensure from concerted, high-quality efforts to solve important problems. Methods will arise from such efforts because the problems will demand them, much the way "systems analysis" arose at The RAND Corporation and aerospace companies because large-scale defense and space problems required something new.

Virtually every topic listed in the previous section abounds with problems that require research. I would like here to call particular attention to some that may not be well known.

Housing and Construction: Since the industry is now highly fragmented and oriented toward short-term profits, research and innovation have had little impact. Builders thus far have made little use of "systems analysis", new materials, or new methods of construction. Much of this slow adaptation seems to have been due to political and institutional obstacles, lack of venture capital, and social inertia.[1] New ideas and approaches, accounting for the strong interaction between engineering and public aflairs, could initiate a true revolution in our ways of costs of living. (Our current houses and communities are surely not the penultimate). Indeed, since the field seems ripe for substantial innovations, private industry should find it most attractive, once the ideas are developed. There seem to be excellent chances for the ventursome to make large (legitimate) profits, so that government need not shoulder the entire housing load.

Clothing: Several thousand years ago, when our current concepts of clothing were formed, only natural materials slightly refined from their natural state were available to be used. Understandably, then, clothing's functions and forms were tailerod to accentuate these materials' strengths and minimize their weaknesses. Today, even though we have hundreds of radically new materials available, we retain, without much modification, patterns shaped to meet entirely different needs. We still regard polymeric materials as "synthetic fibers," to be spun, cut, and formed in traditional ways as direct substitutes for wool, silk, flax, cotton, and leather. Perhaps we should re-examine clothing's basic objectives —functional (control temperature and ventilation "comfortably," provide physical support, etc.) and aesthetic—to see how we might revise our concepts of clothing to take special advantage of the new materials' properties. (That is, we should overcome the "hidden persuaders" of tradition and design inertia.) These new concepts not only might free us from current technical limitations (e.g., permanently bulky materials for Arctic wear, or extensive wardrobes for variable climates) but also might liberate artistic imaginations to create entirely new styles. The rapid adoption of inexpensive nonwoven fabrics (used in so-called paper garments) would indicate that

[1]Building codes have traditionally been singled out as major villains. A new building code that permits the use of new materials, a so-called performance code, has recently been adopted in New York City.

A person educated in engineering and public affairs has the skills to understand technical and social phenomena and their interaction . . . to formulate and test predictive models for the phenomena and their interaction . . . to understand and be able to work with the environment . . . to apply systematic methods for analyzing and synthesizing complex, interacting, large scale systems, in which many things may be uncertain.

popular acceptance under the right conditions should pose few serious problems.

Institutional adaptation: Limiting rates of information flow that govern the diffusion of new ideas, new patterns, and new technologies in organizations are dimly understood. We need research to discover what would be ideal or near-ideal conditions, and to find management principles to speed the diffusion process, to make change simpler and more effective.

Radical Change: While we seem to understand fairly well how to deal with marginal change (i.e., with small improvements in our current ways of doing things), we still seem quite ill-equipped to understand and deal with radical change, with totally new developments, such as the automobile, the jet airplane, and the computer, that permit us to do what could not be done before. We have not done well at predicting even their effects on technology, and we have done far less well at anticipating their interaction with public affairs (what we could term the public adjustment and control problem). While American society seems to have survived this poor anticipation (although it shows a few bruises), some less-developed societies (for whom the changes have been even more radical) have not proved so resilient. Research into the nature of radical change could be most fruitful.

Medicine: In the area of engineering and public affairs, medicine offers considerable challenge in public health, waste management, diagnostics, hospital and clinic location, financing, and organization, child-care and geriatric-care systems, etc. In the area of child-care, for example, one might examine the means, costs, benefits, social ramifications, policy implications, etc., of providing thorough medical-psychiatric attention to young children, especially to those children who now receive no attention at all, (Part of the current difficulty stems from a "profession problem" not unlike that faced among bureaucracies and in parts of engineering.)

Science, Technology, and National Power: It seems ironic that, in the midst of clamor about a "technology gap" and concern over nuclear proliferation, few people are seriously examining the relations between science, technology and national power. Indeed, economists have acknowledged only recently the major role technology has played in American economic growth, and most of their models to date have been correlative rather than explanatory, so that extrapolation to other countries or to the future will be difficult. At the national-international level, it is hard to imagine a much more important area for research. And since it involves detailed interaction between technology and public policy, it demands an approach that transcends either engineering or public affairs alone.

DIRECTIONS FOR EDUCATION:

Although no doubt much engineering-public affairs work will be carried out by multi-disciplinary teams composed largely of specialists, we also appear to need individuals professionally trained in both engineering and public affairs. Within this genre, we might aim for either of two initial "products," depending on the student's inclinations and abilities:

(1) A "sophisticated engineer" aware of the total design context and of legal, political, economic, and social considerations.
(2) A public affairs-oriented person well versed in the procedures and uses of science and technology and in scientific methods of decision-making.

Both types of training would seem to be valuable for research and analysis on problems involving strong engineering-public affairs interaction. And both might also be valuable for policy formulation and administration in the area of engineering and public affairs. The "sophisticated engineer," for example, might have a particular advantage as a project manager on technical projects of social concern.

Worthwhile projects require the cooperation of people with a wide variety of backgrounds—engineers, economists, political scientists, sociologists, architects, lawyers, etc.—and must have a project leader who can coordinate their efforts. To coordinate effectively, the project leader must be able to see the problem as a whole and be able to place the most important specialized sub-problems in the relevant total context. He should have professional competence (although not necessarily expertise) in economics and politics, and be able to organize and hold the respect of a

Limiting rates of information flow that govern the diffusion of new ideas, new patterns, and new technologies in organizations are dimly understood.

team of diverse specialists, to make certain that their contributions work together as efficiently as possible toward the overall objectives.

The scientifically versed public affairs person might be most valuable if he worked in areas where there are important scientific and technical problems, but where technically trained people designated as such have not been given important policy-making responsibility (as, for example, in foreign policy). The man's public affairs training would give him proper credentials. With these credentials he would be able to draw on his technical background to bring scientific and technical considerations into larger policy-making roles. To be effective, however, and to be able to sell his ideas in the face of opposition, he could need more than cursory technical exposure appended to a social science education. His technical abilities and credentials also must be of high quality.

To deal with these problems, the students of both types should be skilled in analysis and experienced, through research and summer work, in using analysis to achieve realistic or "practical" goals. At the minimum, they should be proficient in engineering and economic analysis. If possible, they should be proficient in a number of other social sciences as well. To be most effective, their analytical skills should be long-lived. Thus, we should stress fundamental principles and relevant methematics, so that the students will be prepared to cope effectively with tomorrow's technology and the problems it will bring.

In general, we might say that engineering and public affairs education should prepare a student to

(a) Possess the tools needed to obtain a quantative understanding of technical and social phenomena and their interaction.

(b) Be able to formulate and test predictive "models" for the phenomena and their interactions.

(c) Understand and be able to work with the environment.

(d) Understand and be able to apply systematic methods for analyzing and synthesizing complex, interacting, large-scale systems, in which many things may be uncertain.

PRINCETON UNIVERSITY'S PROGRAM:

Princeton University's program in the area of engineering and public aflairs is still under development. At this point it consists of several alternative routes:

- First, Princeton's Woodrow Wilson School of Public and International Affairs gives careful consideration to applicants who have completed their undergraduate work in engineering, science, or mathematics but who look forward to careers in public affairs requiring preparation in social science.
- Second, the University encourages a person who has earned his Master's degree in a technical or scientific discipline but who does not wish to work professionally in this discipline to develop his skills by supplementing his technical education with academic work in public affairs.
- Third, the University encourages scientists and engineers with some years of professional experience to enroll in the public affairs program. These people may then develop important careers in public programs that require not only technical competence but applied social science knowledge as well.
- Fourth, the Woodrow Wilson School encourages technically educated persons with a strong interest in systematic analysis applied to governmental programs to enroll in the public aflairs graduate program, where they may, in cooperation with the School of Engineering and Applied Science, strengthen their technical and analytical skills and learn to apply them creatively to various governmental programs.
- Fifth, a student who wants to undertake graduate study simultaneously in engineering, and public affairs may follow a combined program of study approved by the School of Engineering and Applied Science and the Woodrow Wilson School. He may qualify for both a Master's degree in Engineering and a Master's degree in Public Affairs.

In addition, engineering graduate students interested in public aflairs are encouraged to enroll in those graduate courses at the Woodrow Wilson School for which they are qualified.

Thus far, Princeton has had about a dozen students who have completed the formal two-degree joint program and many others who have followed their options. Although it is too early to tell whether their joint training has indeed helped them, the few indications available appear encouraging.

ChE laboratory

TAYLOR-AXIAL DIFFUSION

ROBERT R. HUDGINS
University of Waterloo
Waterloo, Ontario, Canada

The phenomenon of axial diffusion is very important to the understanding of chemical reactors and pipeline flow. Yet, the opportunities for visualizing this phenomenon are few. All too often the student must accept a textbook description of axial diffusion without ever being able to observe it. An experiment is described which permits such observation using inexpensive apparatus to give results of reasonable accuracy.

Robert R. Hudgins is assistant professor and associate chairman of the Department of Chemical Engineering, University of Waterloo, Waterloo, Ontario, Canada. He received his BASc (1959) and MASc (1960) degrees from University of Toronto, and his PhD from Princeton University (1964). His research interests are kinetics, catalysis, and reactor design.

THE EXPERIMENT

The apparatus, shown schematically in Fig. 1, is a modification of that used by G. I. Taylor* in his original experiments with axial dispersion in laminar flow. A capillary tube 200 cm in length and about 0.05 cm inside diameter is used. Tracer material is injected into the tube through an axially mounted hypodermic needle of diameter smaller than the capillary bore. The tracer material is a solution of from 1 to 4 per cent potassium permanganate. The flow may be set approximately at any desired value by trial and error. A small bubble of air is injected into the capillary through the syringe, and its progress is timed through a measured length. The elevation of the pressurizing bulb and the opening of the needle valve are adjusted for the desired flow. The average velocity u_m is accurately determined, however, from the progress downstream of the centroid x_1 of the tracer patch.

At this point, the student should calculate the Reynolds number ($Re = du_m\rho/\mu$, where d= inside diameter of the capillary, ρ = density of the liquid, and μ = viscosity of the liquid) to verify that the flow is laminar ($Re < 2300$).

With water flowing at this known velocity, the syringe is filled with $KMnO_4$ solution and a small sample injected into the moving stream. One or two tries are generally required for the student to learn to inject a dark slug of $KMnO_4$ solution into the stream without causing back-

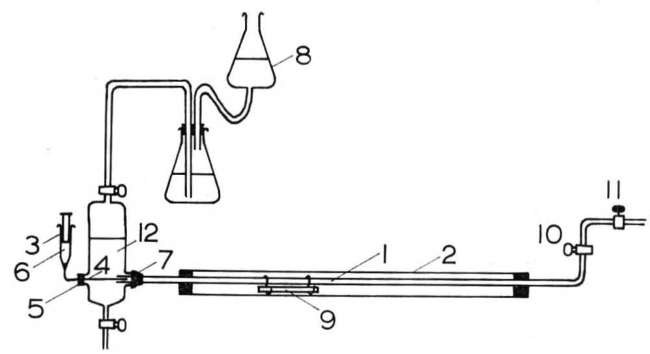

Fig. 1. — APPARATUS — 1, capillary tube; 2, fluorescent bulb; 3, hypodermic syringe; 4, hypodermic needle; 5, serum cap; 6 tracer solution; 7, rubber tube; 8, pressurizing bulb; 9, comparison tube; 10, stopcock "S"; 11, needle-valve; 12, water reservoir.

flow towards the water reservoir. In our experience, however, this method of preparing tracer pulses is more convenient and accurate than the original technique of Taylor. After several minutes, during which the axial concentration gradient is established, a stopcock "S" is closed, flow is stopped and the axial concentration profile is measured using comparison tubes of different strengths of $KMnO_4$ solution. Comparison tubes are cut from the capillary stock material in about 10 cm lengths, and filled with various strengths of $KMnO_4$ solution prepared by diluting the tracer solution with water to form solutions of the following strengths: 1, 2, 3, 4, 6, 8, 10, 15, 20, 30, 40, 50, 60, 70, 80, 90, and 100 per cent of the tracer solution. An adequate measurement can be made using only the solutions above the 10 per cent level; however, the tails of the Gaussian distribution will be sacrificed from the ob-

*Taylor, G. I., *Proc. Roy Soc.*, **A219**, 186 (1953).

servations. In making a comparison, some students find it convenient to construct a piece of paper with a vertical slit about 2 mm wide, and long enough to fit across both the main capillary and the comparison tube. The slit is moved back and forth to where the colors in the two tubes are identical and the x-coordinate of that composition is recorded. The tubes are illuminated from behind by means of a 4-ft 40 watt fluorescent bulb, which provides very uniform lighting.

After the measurements have been made at the first station, stopcock "S" is reopened and flow is resumed until the tracer has moved substantially further downstream. The flow is again stopped, and the axial concentration profile recorded. Typical results are shown in Fig. 2. From these data, estimates are made of the axial dispersion coefficient k, and the molecular diffusivity D of $KMnO_4$ in water.

INTERPRETATION OF RESULTS

Before a simple analytical solution may be obtained for the axial concentration profile, the radial concentration gradient must decay to a fraction of their initial values. At that time the average axial concentration gradient relative to a coordinate x_1 travelling with the mean velocity of the fluid is given by the Gaussian expression:*

$$C = \frac{M}{A} \frac{1}{(4\pi kt)^{1/2}} \exp\left[-(x-x_1)^2/4kt\right] \qquad (1)$$

where M = mass of solute in the tracer pulse, A = cross sectional area of the tube (πa^2), k = the effective axial dispersion coefficient, x = axial coordinate, x_1= the x-coordinate of the centroid of the tracer patch at time t. t is the accumulated time of flow from the moment the tracer is injected. From any concentration profile, the value of x_1 is conveniently determined by averaging the distances between points having the same concentration. From Equation (1),

$$\ln C = \ln\left[\frac{M}{A}\frac{1}{(4\pi kt)^{1/2}}\right] - \frac{(x-x_1)^2}{4kt} \qquad (2)$$

Thus, a plot may be made of ln C versus $(x-x_1)^2$ as in Fig. 3 from which the slope $s = \frac{1}{4kt}$.

*This solution is analogous to that for molecular diffusion from an instantaneous planar source of tracer into a stationary medium, as given by J. Crank, The Mathematics of Diffusion, Oxford University Press, 1956. In the stationary case, the general dispersion constant k is replaced by the molecular diffusivity D.

Concentration profiles are recorded at two different points in the tube, and the resulting slopes are combined to give:

$$k = \frac{1}{4}\left(\frac{1}{S_1} - \frac{1}{S_2}\right)\frac{1}{(t_1-t_2)} \qquad (3)$$

According to Taylor's theory,

$$k = \frac{a^2 u_o^2}{192\ D} \qquad (4)$$

where a is the radius of the capillary, u_o is the maximum velocity, which in laminar flow equals 2 u_m. From Equation (4) the molecular diffusion coefficient D for $KMnO_4$ in water may be calculated.

This experiment is very helpful in demonstrating the role of radial concentration gradients. It can be easily seen from its radial concentration profile that the tracer patch moves down the capillary with a pointed front and a

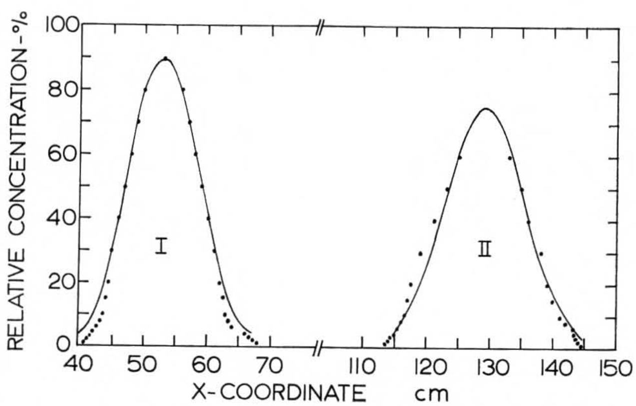

Fig. 2. — STUDENT DATA FOR CONCENTRATION PROFILES — Curve I: t = 840 sec; x_1 = 53.0 cm; Curve II: t = 2340 sec; x_1 = 129.3 cm.

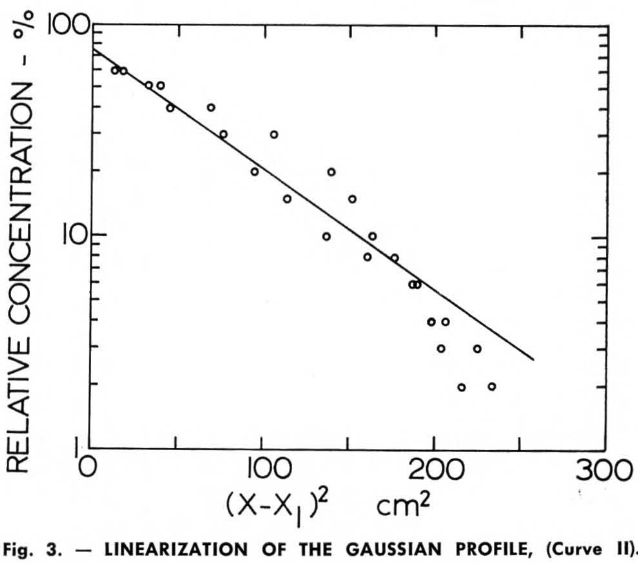

Fig. 3. — LINEARIZATION OF THE GAUSSIAN PROFILE, (Curve II).

hollow rear. When flow is stopped, the radial profile quickly disappears. Estimated from the Einstein relation,* this time of disappearance should be in the order of 20 sec in the present system. After flow is restarted, the radial concentration profile reappears. The student can witness the formation of the axial concentration gradient by noting the presence of a non-uniform (laminar) velocity profile and a small radial variation in concentration both in front of and behind the tracer patch. The fact that the radial concentration gradient has decayed to a fraction of its initial value, while remaining the cause of the axial spreading frequently seems paradoxical to a student who has not seen the dispersion phenomenon. However, actual observation of the dispersing tracer during its journey helps resolve this paradox.

It is a straightforward matter to derive an alternative to Equation (1) to describe a step-input tracer rather than a puse tracer. In practice, however, our experience indicates that step inputs of about 4% $KMnO_4$ solution do not fit the predicted results as well as pulse inputs in a horizontal tube. The discrepancy would appear to result from small density differences between water and $KMnO_4$ solution. The use of pulse tracers obviates this difficulty to a large extent.

Finally, Taylor showed that the characteristic Gaussian pattern did not appear until the following inequality was satisfied:

$$L/u_o << \frac{a^2}{3.8^2 D}$$

An order of magnitude estimate is required for D initially, to estimate how long flow must proceed before the axial concentration profile will become Gaussian. Using the calculated value of the molecular diffusivity, it must finally be verified that the above inequality was, in fact, obeyed.

For the results shown in Fig. 1, the molecular diffusion coefficient was calculated to be 0.7 x 10^{-5} cm^2/sec which compares favourably with Taylor's value of 0.80 x 10^{-5} cm/sec.

ACKNOWLEDGMENT

The author wishes to acknowledge the assistance of Messrs. J. Buchanan and V. Arunachalam in setting up and developing the apparatus.

*$D = \overline{x^2}/2\tau$, where $\overline{x^2}$ is mean square displacement and τ the time over which the displacement occurs. We may set $\overline{x^2} \approx a^2$ for present purposes.

ChE problems for teachers

The following problem on transport phenomena were contributed by Professor Ray Fahien, University of Florida.

A nuclear engineer is interested in predicting the temperature buildup in a nuclear reactor in which an annular fuel element is cooled by maintaining the inner and outer walls at a temperature T_0. The fuel element is initially at T_0 also. At time $t = 0$, the nuclear reaction is permitted to take place and heat is liberated in the annulus at a rate (assume constant) of S_N(Btu/ft^3-hr).

a. Show how his problem is analogous to the momentum transport problem of unsteady state flow in an annulus of radii R_1 and R_2, of an incompressible fluid of density ρ and viscosity μ, with a velocity in the z direction of v_z and under a pressure drop (including gravity) of $(p_o - p_L - \rho g L)/L$.

b. Write expressions for the total heat transport Q Btu/hr from the reactor walls and for the analogous momentum quantity. Repeat for the average velocity V and the analogous energy quantity.

c. Show how a knowledge of V (t) can be used to obtain Q(t).

d. Show that this analogy can also be used in more complicated systems such as those in which several cooling tubes penetrate a cylindrical fuel element even though an analytical solution is not possible. Derive the general relation between V and Q and outline a procedure whereby experimental data on V can be used to obtain Q. State which dimensionless variables should or should not be made the same in each system.

LETTERS (Continued from page 29)

the near-endless font of tax dollars diverting engineering teachers into science research and gradautes into massive science-oriented programs is costing industry so much of the basic engineering talent needed for the expansion and profits to pay the taxes and clean up our environment. If more "scientific engineers" were trained, the outlook for our companies, plants and cities would be healthier.

Rex T. Ellington, Mgr.
Sinclair Oil Corp.

Editor: The article by Dr. Sleicher entitled "Humanities and Social Science In Engineering Curricula" in the Spring, 1968 edition of Chemical Engineering Education was read with interest. Having been exposed to some 18 years of industrial experience with two major United States corporations, the need for development of "values" is readily apparent to me.

How many companies will **deliberately avoid** development of products primarily geared towards destruction of fellow human beings?

How many industries will **take the lead** in controlling pollution, even when the cost will reduce profits and dividends, at least for several years?

How many individual engineers will **consciously turn** the attention of management toward their worthy peers, even at the risk of being passed by themselves?

How many graduate students and their advisors would **refrain from early publication** of a research effort, to avoid destroying the efforts of another group or institution working in a similar field?

In other words, how many of us at any level of our society are more interested in others than in ourselves? Can courses in humanities change these basic patterns of human behavior? Or is a far more drastic, more unpopular and more "unsettling" change needed? And could it be that even 2000 years later, the needed change still begins and ends with the Person who said, "So whatever you wish that men would do to you, do so to them, for this is the law and the prophets."

Leigh E. Nelson
Hastings, Minn.

Editor:

It is gratifying to find that there are others who assert the validity of a macroscopic derivation of the basic equations of irreversible thermodynamics. However, it is not immediately obvious why Professor Wallis considers his derivation more correct conceptually and more useful in practice than ours[**CEE, 2, No. 3, 109-112 (1968)**]. The question of using the idea of "lost work" as opposed to the "rate of entropy generation per unit volume" involves something more than a matter of taste despite the fact that $lw \equiv TS_p$. (It is not clear how Professor Wallis distinguishes between the system property, S, and entropy production, S_p.)

The assumptions inherent in Professor Wallis' Equations (1) and (2) are certainly not less tenable than the assumptions of the bilinear form of the entropy production and the restricted definitions of the fluxes and forces in the microscopic derivation according to Onsager. However, such assumptions must be examined for generality. Although at this point in the derivation there are no limitations imposed on the magnitude of the fluxes or forces, our derivation shows that lost work (or entropy production) can be treated as an exact differential only for the case of discontinuous or steady state systems in which no work is transferred at any stage of the process. Further extension to other processes can be made only as approximations to special cases.

Aside from these details, the critical point in Professor Wallis' derivation, as well as ours, is the utilization of the concept of an exact differential, the significance of which has been apparently overlooked in previous derivations based on the microscopic approach.

As a final point, Professor Wallis raises the question "of just why 's' should be a homogeneous function of the second degree in the fluxes or potentials." In an earlier paper [Sliepcevich and Finn, **Ind. Eng. Chem. Fund. Quart. 2**, 249 (1963)], we attempted to show that the assumption of small fluxes or forces leads to an arbitrary analytic function for which all terms of higher order than two can be neglected as a first approximation. However, such a series expansion raises some questions as to the method of combining the terms without making some a priori assumptions regarding symmetry. On the other hand, to the extent that lost work can be represented as a quadratic in either the fluxes and forces, it seems reasonable to conclude from our Equation (3), and the basic postulates following it, that lost work is a homogeneous function of the second degree in the fluxes or forces.

In summary, the principal difference between our derivation and the one proposed by Professor Wallis is that we have attempted to show how, and under what conditions, the functional form of lost work arises as a direct consequence of the mass, energy and entropy balances and the Gibbs' equation. We prefer this approach rather than simply asserting the form of the function.

C. M. Sliepcevich
University of Oklahoma

Editor:

I have noted with some dismay the continued claims by C. M. Sliepcevich and co-workers to having achieved a derivation of the Onsager reciprocal relations of irreversible thermodynamics from macroscopic principles alone. In-as-much as it is well known that this cannot be done without the benefit of additional microscopic information such as time reversibility in the dynamics of molecular encounters, it is tempting to pass these claims off as being preposterous were it not for their reputation and their potential for misleading the uninitiated. As noted by the authors of the most recent publication, a negation of their macroscopic "derivation" was offered previously by F. C. Andrews, but this criticism has been inconclusive. The matter of whether lost work could be regarded under certain prescribed conditions as being path independent is treated correctly by Sliepcevich et. al.

The actual error in the recent publication occurs as follows: having concluded that the lost work has the generic form

$$dg = X\,dx + Y\,dy \qquad (1.1)$$

with dg an exact differential and X. Y the affinities or &driving forces for transfer conjugate to x and y, the authors use the special case or "rate form" of (1.1) namely

$$\frac{dg}{d\theta} = \dot{g} = X\dot{x} + Y\dot{y} = X\frac{dx}{d\theta} + Y\frac{dy}{d\theta} \qquad (1.2)$$

together with the postulate that g assumes the quadratic form

$$\dot{g} = \alpha\dot{x}^2 + \beta\dot{x}\dot{y} + \gamma\dot{y}^2 \qquad (2.1)$$

with dependence of α, β, γ upon state variables permitted. The argument proceeds by using Eulers theorem to reexpress (2.1) as

$$\dot{g} = [\alpha\dot{x} + \frac{1}{2}\beta\dot{y}]\,\dot{x} + [\frac{1}{2}\beta\dot{x} + \gamma\dot{y}]\,\dot{y} \qquad (2.2)$$

or

$$dg = \dot{g}d\theta = [\alpha\dot{x} + \frac{1}{2}\beta\dot{y}]\,\dot{x}d\theta$$

$$+ [\frac{1}{2}\beta\dot{x} + \gamma\dot{y}]\,\dot{y}d\theta \qquad (2.3)$$

Then by assuming that $dx \equiv \dot{x}d\theta$ and $dy \equiv \dot{y}d\theta$ may be regarded as independent differentials in (2.3), the square bracket coefficients of (2.3) are compared with (1.1) to conclude that

$$X = \alpha\dot{x} + \frac{1}{2}\beta\dot{y} \quad ; \quad Y = \frac{1}{2}\beta\dot{x} + \gamma\dot{y}$$

from which

$$\dot{x} = \frac{\gamma X - \frac{1}{2}\beta Y}{(\alpha\gamma - \frac{1}{4}\beta^2)} \quad ; \quad \dot{y} = \frac{-\frac{1}{2}\beta Y + \alpha X}{(\alpha\gamma - \frac{1}{4}\beta^2)}$$

obey the reciprocity relation. This procedure is, of course, equivalent to identifying the square bracket coefficients of $\dot{x}$ and $\dot{y}$ in (2.2) **individually** with X and Y in (1.2), and is clearly invalid for one could just as well have written (2.2) as

$$\dot{g} = [\alpha\dot{x} - \beta\dot{y}]\,\dot{x} + [\gamma\dot{y}]\,\dot{y} \qquad (2.4)$$

and concluded by the same argument the asymmetrical form

$$X = \alpha\dot{x} + \beta\dot{y} \quad ; \quad Y = \gamma\dot{y}$$

The difficulty with the procedure is that in (2.1) there is but one independent variation, that of the time parameter θ. The source of the difficulty may be traced to the fact that (2.1) with $\dot{g}$ positive definite is not a proper statement of the postulate of irreversible thermodynamics. Rather, it is necessary to proceed from (1.2) with the postulate that the fluxes, $\dot{x}$ and $\dot{y}$ are linear in the affinities, X and Y. to deduce (2.1). Ovbiously the values of α, β, γ are determined by the symmetrical portion of the phenomenological matrix alone, and no amount of manipulating the $\dot{g}$ forms can yield conclusions about the remainder of the phenomenological matrix. Although we have the restriction that $\dot{g}$ is positive definite, there is nothing to say that $\dot{g}$ be an "even function" of $\dot{x}$ and $\dot{y}$.

Finally, your authors seem not to have recognized that if molecular models are even conceivable which violate microscopic reversibility and yet are compatible with the phenomenological approach, one need go no further to conclude that the macroscopic theory per se has no more inherent capability of predicting reciprocal relations than it has of predicting numerical values of transport coefficients, short of direct measurement.

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Acknowledgments

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ChE news

A symposim entitled "A Critical Review of the Foundations of Relativistic and Classical Thermodynamics" will be held April 7-8, 1969 at the University of Pittsburgh. Professor I. Prigogine will be the keynote speaker and Professors A. C. Eringen, E. A. Guggenheim and P. T. Landsberg will deliver papers of paramount importance. The symposium will probe the fundamental concepts, ideas, postulates, and laws of thermodynamics in depth. International participation is expected. For additional information contact: Dr. Alan J. Brainard, Dept. of Chemical and Petroleum Engineering, 103 State Hall, University of Pittsburgh, Pittsburgh, Penn. 15213.

ACS Aids the Disadvantaged

The Council of the American Chemical Society at its San Francisco meeting in April 1968 recognized the needs of the disadvantaged segment of our population in relation to unemployment and lack of education. In mid-summer a special Subcommittee on Education and Employment of Disadvantaged Persons (Project SEED) assembled a biracial panel of ACS leaders to seek out specific ideas, programs, and courses of action by which colleges and universities, the chemical industry, and the ACS could assist disadvantaged persons.

Specific proposals for ACS action now being considered in depth by Project SEED task force groups are as follows:

- **Education in Writing Research Proposals and Grants** — This task force will consider ways to assist small colleges, particularly Negro colleges, in writing proposals for research and teaching grants;
- **Industrial Summer Trainees** — This group will consider ways to encourage the lowering of requirements for industrial summer trainees and suggest a mechanism to encourage industry to expand its summer hiring program overall.
- **Education of High School Guidance Counselors** — This task force will consider a program to describe to guidance counselors, particularly in disadvantaged areas, the career opportunities in science.
- **Project Catalyst** — Last summer, the ACS sponsored a pilot program in which 10 disadvantaged students were employed for the summer at college or university laboratories. This task force will evaluate last summer's program and make plans for a similar program for next summer to involve perhaps as many as 500 underprivileged students. The task force is also expected to consider the possibility of a winter Project Catalyst program in which jobs will be provided for high school students in university laboratories in the afternoons or evenings.
- **Technicians Employment Service**—The task force will try to determine if the ACS could develop a technicians employment service to provide hiring and training assistance to disadvantaged people.
- **Veterans Training and Employment Programs** — Returning veterans from disadvantaged areas are constantly faced with the problem of lack of job opportunities. The task force will attempt to develop plans which can be implemented in cooperation with the ACS local sections and with local industries to provide meaningful training and hiring programs to benefit returning veterans.
- **Refresher Training for Graduates from Small, Less Efficient Colleges** — This task force will attempt to develop a plan or program for providing refresher training for graduates of these schools to enable them to meet the requirements and standards of graduate schools.
- **Upgrading Small Colleges**—This task force will investigate ways in which the ACS might act to upgrade the smaller institutions and provide the necessary resources and advice to assist these small schools.
- **Tutorial Assistance** — This task force is endeavoring to establish a national program to provide tutorial assistance to disadvantaged students at all levels.

Each of the task force groups will also consider the relationship of the proposal under study to other programs which may be presently under way in other organizations.

This information was furnished by Dr. Stephen T. Quigley Director of Office of Chemistry and Public Affairs, ACS 1155 Sixteenth Street N. W., Washington, D. C. 20036 who may be contacted by interested readers for details on current needs and accomplishments of Project SEED.

CANON AND METHOD IN THE ARTS AND SCIENCES*

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In a famous passage of his Gifford lectures, "The Nature of the Physical World", Sir Arthur Eddington compared the mathematician's and the poet's view of waves generated on water by the wind. In the first, two expressions relate the surface forces to the constants of the waveform leading to the conclusion that a wind of less than half a mile per hour will leave the surface unruffled, capillary waves appear at one mile per hour and gravity waves at two. For contrast Eddington quotes the beautiful sestet of the fourth sonnet in Rupert Brooke's cycle '1914'.

> There are waters blown by changing winds to laughter
> And lit by the rich skies, all day. And after,
> Frost, with a gesture, stays the waves that dance
> And wandering loveliness. He leaves a white
> Unbroken glory, a gathered radiance,
> A width, a shining peace, under the night.

The comparison is most sensitively drawn and its rapier ring makes some of the more recent exchanges in the conflict of the cultures sound like the clang of clashing cutlasses. Eddington had previously shown how farfetched is the physicist's picture of the real world — "it is not reality but the skeleton of reality"[1]—and he goes on to contrast 'symbolic knowledge' with its analytical techniques with the 'intimate knowledge' that defies codification. This is not the place to pursue or defend Eddington's epistemology, but the example provides a delicate statement of the problem of the relation of the sciences to the humanities.

It is hard to resist the feeling that here is a matter of deep significance to which the scientist and engineer should be increasingly sensitive. We are fortunate at Minnesota to have an exceptionally fine course in our Humanities department that makes this issue a matter of lively concern. This course, initiated and taught with more than ordinary verve and perception by my colleague Mischa Penn, opened my eyes to the depth and subtlety of the problem and I confess that I find it difficult and elusive to a degree — far more difficult to get to grips with than the more mundane research that I pursue in the context of chemical engineering science. It is not that the latter is a banaustic enterprise, uncongenial to the atmosphere of a university, for in fact — at any rate in the department in which I have the good fortune to be a member — it has much of the spirit of natural philosophy in the sense which that term acquired in the 17th centurn and in which it is understood — when it is understood — today. One aspect of the difficulty can perhaps be illustrated in one of the words of my title.

Used in a mathematical context, the word 'canon', or more usually 'canonical form', must be defined precisely and all deviations rigidly excluded. Thus the Jordan canonical form of a matrix is a unique presentation of it and can be determined by a finite sequence of operations. But used in a literary context — even in one so humble as a title — the word 'canon' immediately recalls rich overtones. The original word in Greek was for a reed when used as a tool and later a tool whether made of reed or not. Most often it is the tool of the builder or carpenter, used to measure length or check level and direction. Besides being straight it had to be inflexible and was often provided with a scale. From this come the metaphorical meanings: (i) written laws or standards of ethics or behaviour; (ii) the exemplary man; (iii) the rules of philosophers and grammarians; (iv) an ordinance fixing tribute; (v) a list or index (derived from the marks on a scale); (vi) the canon of the mass (derived from the associated lists of

*The substance of this paper was given as one of the Olin Lectures in the Department of Engineering and Applied Science at Yale in February 1968.

The motivation of the natural philosopher is surely the compelling desire to see the structure of his subject and the longing to carve out an understanding of some part of it that will be significant in content and beautiful in form.

saints). There are a number of quite special meanings such as the ear of a bell, a size of type and mode of musical composition and there is the normal christian usage, current since the second century,

ὁ κανῶν τῆς πίστεως,

or the 'regula fidei'. Of course in the title the word means a standard of judgment, but the point is that the literary use immediately evokes a whole spectrum of meaning in a way that the scientific does not.

This difference between the arts and sciences is however a superficial one and the bonds that unite scholars from all disciplines are far stronger and more significant than the divisive influences. Moreover it seems of vital importance that engineers should retain a lively appreciation of this, both in industry and the university. Without it, there will be no vision among the captains of industry and the people will surely perish: without it, the university will certainly degenerate into that atrocious artifact of the administrative mind, the "multiversity". I would like to suggest that a sense of craftsmanship and a feeling for form and structure are foremost among the sympathies that will keep the sciences and humanities together, however diverse their expressions of these may be. The historian and philosopher, just as often as the physicist or mathematician, must have wished, whilst listening to a symphony of Mozart's or a quartet of Beethoven's, that he could write just one paper of comparable quality, that he could present the key thesis of each section with that kind of clarity, develop it with like finesse, interweave it with the other threads of his argument as subtly and recapitulate with such power.

The motivation of the natural philosopher (be he mathematician, pure or applied, chemist, physicist, engineer or what have you) is surely the compelling desire to see the structure of his subject and the longing to carve out an understanding of some part of it that will be significant in content and beautiful in form. To this end he will use the canons of his craft — *rigour*, *elegance*, *seriousness* and *universality* — as may be illustrated by considering one of the elementary theorems of the theory of numbers.

The Greeks were well acquainted with the integers and with rational numbers, but they also had equations like $x^2 = 2$ for the ratio of the length of the diagonal to the side of a square. What is more they had the penetration to ask the question, "Is the square root of 2 a rational number?" The proof that it is not is commonly attributed to Pythagoras and, as a simple exemplar of the canons I have mentioned, it can scarcely be improved upon. For suppose there are mutually prime integers such that $p/q = \sqrt{2}$, then $p^2 = 2q^2$. But since the factors of p^2 are just those of p duplicated and 2 is a factor of p^2, it must also be a factor of p. Let $p = 2r$, then $p^2 = 4r^2 = 2q^2$ and $q^2 = 2r^2$. But now the argument can be repeated to show that 2 is a factor of q and this is contrary to the hypothesis that p and q had no common factor. It therefore follows that there are no integers such that $p^2 = 2q^2$. There are pairs of integers such as 1,414,213,562 and 1,000,000,000 that will suffice for any practical purpose, but none that will satisfy the equation perfectly.

The canons of rigour, elegance, seriousness and universality are fully exemplified here. Rigour is maintained by the precise logic of the demonstration. There has been neither looseness of thought nor approximation in number. Elegance is seen in the spare economy of the proof and in the classic beauty of the 'modus tollendo tollens'. The notion of seriousnes, as Hardy calls it in his "Mathematician's Apology",[2] is more difficult to define, but it is clearly present here in the way in which the class of object we have called numbers is enlarged. The theorem tells us that close packed though the rational numbers are, they are not the scales of leviathan and an irrational can come between them. Finally, its universality is seen in the fundamental importance of the number system, pervading much of mathematics and most of science.

Now the same canons surely apply in litterae humaniores. The rigour of the mathematician is mirrored in the formal constructions of the arts, in the logic of a philosophical argument or the build up of evidence in an exposition of history. Admittedly it is the fashion in some of the arts today to break down the form. At one time we used to be told that an artist could only safely take to the abstract mode after he had first mastered the traditional disciplines of his craft. His breaking down of the form was then held to be an extension of it to new modality and meaning. Nowadays we are not often encouraged to seek meaning in art and the cramping effect of discipline on creativity is held to be so serious that it can be safely dispensed with. Yet a large body of art remains to show us that form does not destroy creativity — the peotry of the Divine Comedy is not diminished by Dante's acceptance of the restrictions of *terza rima,* rather it is enhanced by his mastery of it. Stephen Spender in a most interesting essay on "The Making of a Poem"[3] speaks of the terrifying challenge of poetry. "Can I think out the logic images?" he asks. "How easy it is to explain here the poem that I would have liked to write! How difficult it would be to write it. For writing it would imply living my way through the imaged experience of all these ideas, which here are mere abstractions, and such an effort of imaginative experience requires a lifetime of patience and watching."

Again, is it not the principle of economy, which is the hall mark of scientific elegance, also a keynote of humanistic thought? Ockham's razor was propounded in a philosophy dominated by metaphysics: it was adopted and adapted by the natural philosophers — "we are to admit," says Newton, "of no more causes of natural things then are both true and sufficient to explain their appearances; for nature is simple and affects not the pomp and superfluous causes."[4] In letters or in verse we commonly deplore excess verbiage and for a writer to be told some of his words are not bearing any weight is damaging criticism indeed.

The canon of seriousness in science has nothing to do with possible application to the useful arts any more than seriousness in the humanities has to do with solemnity. Hopkins' sonnet[5]

> "I caught this morning morning's minion,
> kingdom of daylight's dauphin, dapple-dawn-
> drawn Falcon . . ."

is serious enough, as its superscription "To Christ our Lord" shows, but it banishes all notion of solemnity in a burst of holy hilarity. There is plenty of verse and art that is solemn enough, but which it is more than a little difficult to take seriously.

The canon of seriousness in science has nothing to do with possible application to the useful arts any more than seriousness in the humanities has to do with solemnity . . . if the canons of their several arts should tend to bring together the humanist and scientist, must they not be forced apart by the diversity of their methods? . . .

Finally we look for some note of universality in humanistic work of real significance. We value the Aeneid, pace the quondam Professor of Poetry at Oxford, not because the adventures of Aeneas were superior to those of other wanderers, but because in recounting them Virgil has touched on so many themes of human experience with that terseness and penetration which is one of the chief glories of the Latin tongue. It is this quality of universality that made it possible for Ronald Knox to use couplets from the Aeneid to illumine an altogether different wandering and adventure.[6]

But if the canons of their several arts should tend to bring together the humanist and scientist, must they not be forced apart by the diversity of their methods? Here again I would plead that there is as much, if not more, in common than there is to divide, and that a lively appreciation of each others methods would promote a valuable sympathy between scientist and humanist. The genesis of a poem or work of art, a critical essay or philosophical discourse, a mathematical discovery or an engineering invention lies in an idea or problem and the act of creation can only begin with the recognition of it. The literary critic is the engineer of the world of letters for he is concerned to bring out into the light and into action the work of the author just as the engineer seeks to apply the discovery of the scientist. This does not mean that there is not a creative, or recreative, element in good engineering or in good criticism, but criticism is, in a sense, a derivative activity. The "Diary of Anne Franck" lies in paperback alongside a dozen gripping and even perceptive books of the second world war and many have been moved by the reading of it. Yet if John Berryman is correct, no one has really perceived the masterpiece that it is, nor got down to the critical problems that a worthy analysis of it would present. Here is the recognition of a problem at the root of the work of a humanist. It is comparable to the recognition of an idea at the root of a work of art. Among humanists, the poet is par excellence the opener of eyes, showing us the significance of some matter. In the realm of the sciences the mathematician is par excellence the refiner of concepts, turning and shaping them until they are precisely true to experience. Each, in his way, sits like a diamond cutter over a stone, seeking the cleavage plane of truth along which the slightest blow will open up the rough gem and reveal the perfection of its intrinsic beauty. Each however has the problem of recognizing the true worth of the matter beneath its rough, amorphous exterior. This first phase of recognition may include the inspiration of the moment in which the artist conceives the idea that he wishes to bring to birth according to his metier, but may be distinguished from the moment of illumination, in which the resolution of a difficulty may appear, or the moment of vision in which the toilsome ascent of a Pisgah is suddenly rewarded.

But, granted the recognition of the problem or idea, there follows for both scientist and humanist the gestative period of cogitation. Ideas and images, many of them unfruitful and inappropriate, are mulled over and mixed together, taken to pieces and reassembled. Stephen Spender speaks of concentration as the sine qua non of creative writing. He distinguishes it from "the kind of concentation required for working out a sum. It is the focusing of the attention in a special way, so that the poet is aware of all the implications and possible developments of his idea, just as one might say that a plant was not concentrating on developing mechanically in one direction, but in many, towards the warmth and light with its leaves, and towards the water with its roots, all at the same time".[3] Perhaps this is different in kind from the concentration required for "working out a sum" by a routine method, but it is precisely the sort of concentration that is required for fruitful original work in the sciences.

Some, it would seem, are gifted with the ability to work out a complete structure in their heads, as Mozart is said to have composed much of his music. Others like Beethoven have to feel their way through draft after draft towards a final statement. From the mine of his memory or the recesses of the subconscious where the

. . . in this craft of our common language should lie the first and final bond between scholars of all disciplines, for all have the same interest in maintaining a sound currency of words.

composition had been going on, Mozart was able to set down the overture to Don Giovanni in a single night but the main theme of the first movement of the Beethoven's 7th Symphony emerged only after six pages of "changing, reflecting, and testing", as he himself described it.

Into the art of heuristic in a mathematical context George Polya has given most valuable insights by his work on mathematical discovery.[7] He shows very vividly how the problem may be tackled, how one works from both ends in searching out the pattern of the solution and how induction and analogy play their role in plausible reasoning. In plausible reasoning the formal modes of demonstrative logic become tentative. For example, the modus tollendo tollens must be replaced by "A implies B, but B is unlikely, therefore A is less credible." This is the kind of reasoning which is used, not only in feeling out the way to the solution of a problem, but also in understanding a demonstrative argument and in gaining confidence in it. Indeed Polya concludes the second of the Princeton volumes with the remark that "we are led to suspect that a good part of our reliance on demonstrative reasoning may come from plausible reasoning."

This emphasis on the process of creation is not to deny the importance of inspiration and the flash of illumination. The classic examples the Poincaré gives in his "Science et Méthode" are so well known that they need not be repeated here. They show, as he himself said, that sudden illumination is a manifest sign of previous subconsicous work perhaps over a long period.[8] There must surely be an analogy here with the resolution of "Problems" as they may arise in humanistic scholarship and creative art. At times the several stages of the creative process seem to have been fused into one incandescent period of intense activity. One thinks of Handel completing the "Messiah" in little over three weeks between August 22 and September 12 of 1741, of Schubert writing no less than eight songs on October 15, 1815 or of his sending his song "The Trout" to Josef Huettenbrenner, calling it "another one which I have just written here at Anselm Huettenbrenner's at twelve o'clock midnight". These are the exceptions that

Among humanists, the poet is . . . the opener of eyes; (among scientists) the mathematician is . . . the refiner of concepts . . .

prove the rule that the beauty of creative work in the sciences or the arts is more the shine of "plough down sillion" than "the hurl and gliding" that rebuffs "the big wind".[5] Often too the moment of luminence in literature or philosophy cannot come without the laboured argument or prior discipline. "He who has been instructed thus far in the science of Love, and has been led to see beautiful things in their due order and rank", says Diotima, "*When he comes toward the end of his discipline,* will suddenly catch sight of a wondrous thing, beautiful with the absolute Beauty".[9] The main body of the 15th chapter of St. Paul's first letter to the Corinthians is a lengthy discussion of the reality of the resurrection. But then comes a pause — a reticence of holy writ, as St. Peter Damian has it, "wherein silence itself cries out that some greatness is at hand" — before the incomparable majesty of "Behold I show you a mystery; we shall not all sleep, but we shall all be changed; . . ." I am not for a moment suggesting that this is mere rhetoric — it is vastly more — but, if it has the divine qualities of revelation, it has also the human beauties of a great work of art.

The final stage of polishing or verification is of equal importance though perhaps calmer than the others. The imaginative leap having been made, logic takes over to tighten up each part and to ensure that the connections are sound. The kind of imagination needed here is that which is capable of keeping the whole structure — poem, paper or prelude — in its proper portion and scale. As any editor of a scientific or technical journal will testify this is an aspect of the presentation of research that receives all too little attention, and perhaps scholarly journals in other fields suffer in the same way.

But surely in this craft of our common language should lie the first and final bond between scholars of all disciplines, for all have the same interest in maintaining a sound currency of words. Perhaps the breakdown of commerce between the arts and sciences, whenever it obtains, is a reflection of the inflation of the domestic currency within each camp. The great words of the tradition of western civilization — liberal, intellectual, rational, humane — are in danger of becoming a paper currency with no backing, deprived of their buying power as effectively by academic verbicides as some of the words of our common life — trust, friends, gracious — have been abused by the writers of newspaper headlines and advertising copy. There was a time when Latin was the lingua franca of the educated world but, serviceable enough though it still would be, there is little hope of reinstating it. We may have to learn to read two or three other languages in order to keep up with the literature of our professions, but we rarely attempt to write in anything but our native tongue. All the more reason therefore that we should cultivate this to the best of our ability, perhaps to find through this medium, not a massage, but the common empathy that is needed if our universities are to remain centres of liberal learning.

REFERENCES

1. A. S. Eddington. The Nature of the Physical World. London. Dent. Everyman's Edn. p. 307.

2. G. H. Hardy. A Mathematician's Apology. Cambridge University Press, Cambridge. 1940.

3. S. Spender. The Making of a Poem. Norton. New York. 1962. p. 54.

4. I. Newton. "De Mundi Systemate". Hyp. I.

5. G. M. Hopkins. Collected Poems. "The Windhover".

6. R. Knox. Spiritual Aeneid. Longmans, Green and Co. London. 1919.

7. G. Polya. Mathematical Discovery. Vols. I and II. John Wiley and Sons, New York. 1962, '65. Mathematics and Plausible Reasoning. Princeton University Press. 1954. "How to Solve It". Doubleday-Anchor, New York. 1957. I have endeavored to illustrate his ideas in a chemical engineering context in the Teacher's Manual to my forthcoming "Elementary Chemical Reactor Analysis". Prentice-Hall, Englewood Cliffs. 1969.

8. See J. Hadamard's "Psychology of invention in the mathematical field" for a considerable discussion of this. Graham Wallas in "The Art of Thought" (1926) comments on the experience of Poincare and the psysicist Helmholtz.

9. Plato. Symposium 211. Translation is Bridges' in his anthology "The Spirit of Man." (1915).

Dr. Rutherford Aris was born in England in 1929, studied mathematics in the University of Edinburghand taught it to engineers there. He has degrees from the University of London (B.Sc. (Math); PhD. (Math. and Chem. E.); D.Sc.). He worked a total of seven years in industry, but since 1958 he has been in the Chemical Engineering Department at the University of Minnesota enjoying the liveliness of its interests, both technical and cultural, and endeavouring to contribute to this vitality and communicate it to his students.