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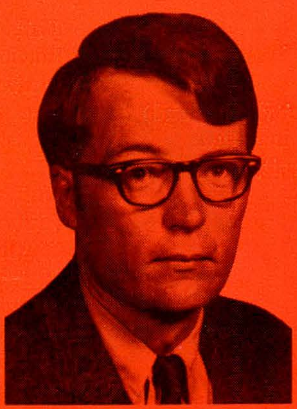

The Compleat Man

DICK SEAGRAVE

of Iowa State

CHE AT STANFORD

CAREER GUIDANCE

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ChE Career Guidance

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ChE department

STANFORD

DAVID M. MASON
Stanford University
Stanford, California 94305

Chemical Engineering at the Leland Stanford Junior University became a discipline within the Department of Chemistry during World War II and was directed for about a decade by Carl Lindquist and Bob Paxton. In 1955 Dave Mason and Neal Pings of Cal Tech moved northward across the Tehachapi mountain range to Stanford and were the two sole faculty members of chemical engineering which that year became a division of the Department of Chemistry and Chemical Engineering. Bill Schwartz joined the faculty in 1957, Bob Johnk in 1959, John Zahner and Andy Acrivos in 1962, Michel Boudart in 1964, Bob Madix in 1965, John Lind in 1967, Bud Homsy and Channing Robertson in 1970. Neal reversed his trek and moved southward across the Tehachapis to return to Cal Tech where he now heads up the Chemical Engineering group and is Dean of Graduate Studies there; Bill Schwarz returned to teach at his Alma Mater, Johns Hopkins; Bob Johnk chairs the Department of Chemical Engineering at San Jose State University, and John Zahner is an industrial tycoon in the field of catalysis with Mobil Research and Development Corporation.

In 1960 Chemical Engineering became a separate department in the School of Engineering, but we have endeavored to maintain close intellectual ties, as well as geographical propinquity, with the Chemistry Department. Two of our eight members currently have joint appointments in the two departments, and our facilities are in the midst of the Chemistry complex. In 1955 we occupied a dilapidated one-story sandstone storage building fondly known as the "outhouse" which with all its nostalgia was razed in 1965. That year the Department moved into a new laboratory and gazebo conference building, made possible by a grant from the National Science Foundation with matching gifts from Mr. John Stauffer and other private donors.

Our undergraduate student body is small, with an average of seven bachelors degrees having been offered per year in the past decade. Most of our baccalaureates go on to graduate school, usually at other institutions. During this decade our graduate program has expanded in scope and degrees awarded increased from 4 M.S. and 2 Ph.D. to 25 M.S. and 8 Ph.D. About one fourth of our doctoral students have perpetuated the species by going into teaching at institutions all over the U.S., the remainder going into industrial positions.

THE FACULTY

Our current faculty can be best characterized by the group shot down in Figure 1 taken during a recent typical faculty meeting in which we were discussing whether or not one of the best graduate students ever to come here, Warren Wonka, had passed, conditionally passed, or conditionally failed his Ph.D. qualifying examination. Michel has elegantly spoken his piece and has turned to the more serious matter of planning a lecture junket to Brussels via Tokyo. Dave has a class coming up and is anxious to spend a few mements culling out his lecture notes from the voluminous University committee reports in his

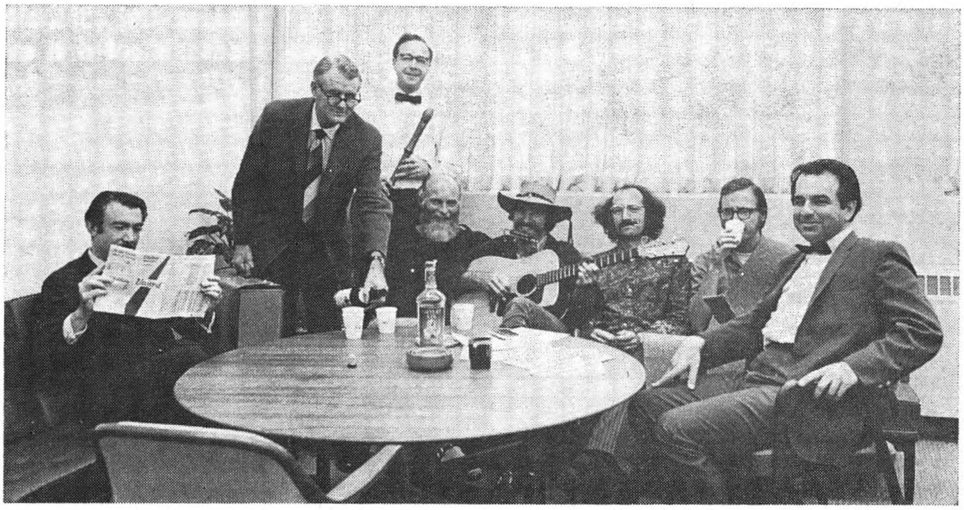


Fig. 1. Full attendance at the "ChE Faculty Club" includes (left to right) Professors Boudart, Mason, Lind, Wilde, Madix, Homsy, Robertson, and Acrivos.

brief case. He is vainly attempting to get the debate off dead-center by offering to his colleagues several different cuts of Stanford spirits from our unit operations, 20-plate bubble cap column. To help make the deliberations even more mellow, a trio consisting of John, Doug, and Bob have just completed a rousing rendition of "The Rose Bowl Fighting Song" with the Ithaca recorder in the key of B^b, the Palo Alto Irish tenor in C^-, and the Urbana guitar in G#. Bud and Channing, being newcomers to the faculty, are totally perplexed and dismayed by the whole proceedings. Andy seems particularly pleased at this point for, most unusual for him, he is about to pull a coup and end the debate with a stunning motion that Wonka be passed conditionally provided that the Ph.D. research in "social thought" he has proposed, be done in another department or university. The deadlock was broken, and it took merely two more liters of Stanford spirits and three more musical verses before the phrasing of the motion was letter-perfect and we stood adjourned.

THE TEACHING AND RESEARCH PROGRAM

After faculty meetings, we wend our way back to our research lairs and offices and purportedly engage in the following research activities which are listed in the order of the faculty member's surname — not necessarily in descending order of relevance and importance.

ANDREAS ACRIVOS — Laboratory for Fluid Mechanics

A distinctive feature of the research effort in this laboratory is that the research is directed toward a number of very basic rather than applied problems in fluid mechanics, whose solution will strengthen the theoretical foundations as well as our overall understanding of many of the key principles in this broad field. With this general goal in mind, then, the research students in this laboratory are encouraged to examine a number of such problems before selecting a particular project which to them would seem to offer the best opportunities for an important contribution of a scientific type.

The projects currently under study both theoretically and experimentally are as follows:

Steady High Reynolds Number Flows with Closed Streamlines — It is well known that the classical laminar boundary-layer theory applies only as long as the flow remains unseparated and that at present no theories exist for describing high Reynolds number steady flows in separated flow regions or regions with closed streamlines. The aim of this project then is to develop such a theory, not only because this would be of interest in itself, but also because such a theory is essential before many of the most basic laminar flows can be properly understood.

The Motion of Freely Suspended Particles in Shear Flow — An important area of fluid mechanics, deals with the motion of small spheres and cylinders in shear flow. The main objective of this part of our research program is to investigate, both theoretically and experimentally, a number of key problems within this broad category, with a view to obtaining a firm understanding of some of the phenomena involved, principally those associated with the rate of heat and mass transfer from the particles to the surrounding fluid.

The Development of Constitutive Equations for Non-Newtonian Fluids — Knowledge of the constitutive equation for non-Newtonian fluids is an obvious prerequisite for any successful study of flow phenomena involving such complex fluids. So, one of our efforts has been to try and obtain such constitutive equations from a more physical point of view using suspension theory.

Elastic and Thermal Properties of Composite Materials — A theoretical analysis has been initiated, whose aim is to relate the bulk elastic and thermal properties of composite solid materials to the corresponding properties of the constitutive parts. Specifically, one desires to find out to what extent the addition of relatively small amounts of suitably chosen foreign substance can affect such parameters as the bulk elastic modulus or the thermal conductivity of a simple solid. There are valid theoretical reasons for believing that the effects of such inclusions could be substantial, especially when such inclusions consist of long and slender particles whose net effect is to render the material non-isotropic.

MICHEL BOUDART — Laboratory for the Study of Adsorption and Catalysis

In building up this laboratory at Stanford University, our guiding principle has been to create a place where a small number of graduate students and post doctoral fellows interact with visitors from university and industry in the pursuit of knowledge in the various active areas of research in heterogeneous catalysis.

Thus, no exclusive emphasis is placed on any particular book, technique or method of approach. Rather, each member of the laboratory is encouraged to follow his own interest and, in so doing, he stimulates the other members of the group engaged in their independent work.

Low Energy Electron Diffractions (LEED) — This technique provides information on the arrangement of atoms at the surface of single crystals. The rearrangement of surface atoms following adsorption or reaction, as well as the superstructures exhibited by adsorbed atoms and molecules, may explain some of the characteristics of solid catalysis. The adsorption and decomposition of hydrocarbons on metals are under study in the LEED apparatus, now provided with Auger electron spectroscopy.

Catalytic Activity of Supported Metals — The stereospecific hydrogenation of complex molecules on various metals is being used as a test reaction to determine how selectivity and activity of a reaction depend on dispersion of the metal.

Our undergraduate student body is small . . . most of our graduates go on to graduate school . . .

Infra-red Spectroscopy of Surfaces — The performance of crystalline alumina-silica catalysts in the cracking and isomerization of hydrocarbons is strongly dependent on the type and concentration of exchangeable cations present in the crystal. The role of these cations in physical and chemical adsorption of gas molecules is being investigated with infra-red spectroscopy.

Mössbauer Spectroscopy of Surfaces — Mössbauer spectroscopy is now used systematically as a tool to investigate surface states of zeolites and various commercial and theoretical catalysts. The characteristics of Mössbauer spectra throw a bridge between surface chemistry and Mössbauer spectroscopy.

Electronic Defects as Active Centers — The low temperature activation of hydrogen as indicated by the hydrogen-deuterium exchange reaction is studied on semiconductor surfaces containing foreign transition metal ions in certain oxidation states. New active sites have been identified with esr spectroscopy.

GEORGE M. HOMSY — Laboratory for Fluid Mechanics and Stability

This program has just been initiated and will have as one of its goals the treatment of applied engineering problems using a rational approach firmly based on continuum mechanics. Initially at least, the emphasis will be on theoretical analyses. Projects are contemplated in the following areas:

Fluidization — Although the motions of fluidized beds are felt to be describable by continuum equations, the exact form of these equations remains a source of controversy. In postulating constitutive equations for the bed and the mathematical form of the particle interaction terms, one is almost forced to rely on intuition. It is proposed to put the phenomenological treatment on a sound basis using results from suspension theory when possible. The problem of bubble genesis in fluidized beds will be viewed as a stability problem. Such an approach requires a wider interpretation of stability than the classical linear sense, and relies heavily upon energy considerations.

Stability of Thin Films — The flow of liquid films under the action of gravity and influenced by surface active agents is of central importance in chemical engineering. Although the linear theory of the stability of such films is reasonably well understood, the mechanism of the growth of disturbances to an equilibrium amplitude and the accompanying changes in heat or mass transfer rates have not been considered.

Rotating Fluid Mechanics — Rotating fluids seldom behave in a manner predictable from our knowledge of non-rotating systems. In many instances the fictitious Coriolis and centrifugal forces exert extraordinary control over fluid motions, making predictions of (say) the heat transfer behavior difficult. Studies of thermal convection and instabilities in geometries of engineering importance are contemplated.

JOHN E. LIND — Laboratory for the Study of the Properties of Fluids

This research is directed toward an understanding of the molecular structure of Newtonian fluids and of the relation between this structure and the transport properties. Momentum, mass and charge transport, as characterized by the coefficients of viscosity, diffusion and electrical conductivity, are of primary interest. The properties as well as the equilibrium thermodynamic properties are being measured over a wide range of temperatures and pressures for various model systems.

Fused Salts — Of prime importance is the question of how greatly the coulomb interactions in a salt melt or a concentrated solution contribute to transport in the melt. Contributions by these long-range coulomb forces are difficult to evaluate from theory. Therefore, an estimate of this contribution is being obtained experimentally by the direct comparison of the transport properties of nonelectrolytes with those of salts whose molecules are essentially isomorphic to the molecules of the nonelectrolyte except for the charge. This comparison is made with the solvent and salt at the same temperature and density. A comparison equilibrium thermodynamic properties such as the compressibility also gives indications of the differences in the microscopic structure of the liquids, and perturbed hard-sphere equations of state are used to understand the phenomena.

Concentrated Solutions — The understanding of fused salts is being extended to the structure of salts when very small amounts of nonelectrolytes are added to the salts. Such solutions provide a very sensitive probe into the correlational effects arising from the coulomb field in the salt.

ROBERT J. MADIX — Laboratory for the Study of the Reactivity of Solids

The research in this laboratory is directed toward the study of collisions between gases and solid surfaces. In particular, modulated molecular beam techniques are employed to study corrosion processes which lead to the formation of volatile products. In addition, the energy transfer to solids accompanying exothermic solid-catalyzed reactions is being investigated. The objective of this research is the simultaneous determination of the energy accommodation and recombination coefficients of atoms on solid surfaces.

Molecular Beams — In order to study the elementary steps of adsorption and catalysis, gas molecules in well-defined energy states must be allowed to interact with well-characterized single-crystal surfaces and the ensuing reaction events observed. Furthermore, if reactions on the surface are to be understood, the nature of the surface intermediates must be known.

For such fundamental studies, the modulated molecular beam offers maximum definition of reactant conditions. A beam of gas molecules in a selected energy state is directed on a single-crystal surface and the reaction products are observed mass-spectrometrically. The beam is interrupted periodically by a shutter so that the product signal may be detected at a particular frequency. This a.c. detection technique allows the determination of rate constants on clean surfaces.

Energy Transfer in Reactive Collisions — The energy accommodation of hydrogen atoms recombining on solid surfaces was studied with a diffusion tube. Atoms were generated by an electrical discharge at one end of a closed Pyrex tube. Since the atoms recombined on a metal surface at the opposite end of the tube, a concentration gradient was established along the tube axis. Determination of this gradient allows calculation of the recombination coefficient on the metal surface. The energy accommodation coefficient was determined by measuring the heat input to the metal per recombining atom. It was found that, in general, the molecules formed left the surface

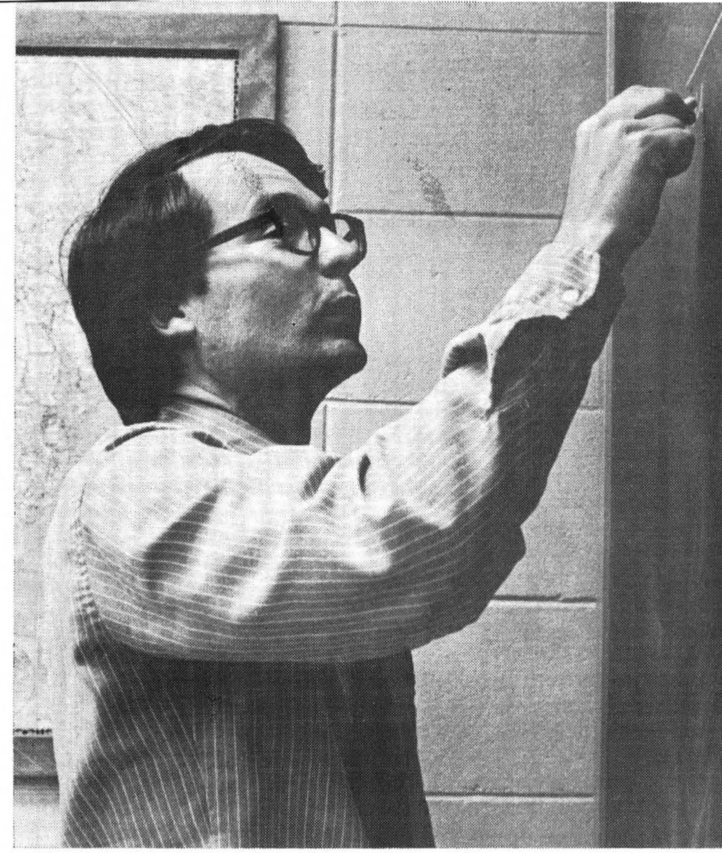
(Continued on page 121)

ChE educator

FROM SMOKE-FILLED ROOM TO IVORY TOWER---

DICK SEAGRAVE, THE COMPLEAT MAN

T. D. WHEELOCK
Iowa State University
Ames, Iowa 50010



"Dr. Seagrave is one of the few instructors who can constantly reach into his bag of tricks, period after period, to keep tired students on the edge of their seats. He succeeds in relating technical principles to everyday occurrences. For instance, in his momentum transfer course, typical questions are, 'prove or disprove the old-timers' baseball adage that a hit baseball goes less distance on a hot muggy day' or 'show why the knuckleball flutters when Hoyt Wilhelm lets one go at 60 mph on a cool day in Candlestick Park.'" — Jerry Schnoor.

"Christmas crowds at the supermarket will always symbolize diffusion of mass for me. Our Thanksgiving turkey is no longer a feast bird; it's purely heat transfer. Gas movements were exemplified by Dr. Seagrave himself, charging around the classroom at top speed, hands flying." — Parviz Salehi.

Student remarks such as these show why Dick Seagrave is a very popular teacher and help explain why Dick received one of the Outstanding Teacher Awards at Iowa State University this year. Dick's interest in transport operations runs deep among the streamlines and eddies of this subject but making abstract concepts meaningful to students is a challenge he meets with uninhibited joy and enthusiasm. Unconventional but fresh and illuminating analogies have become a Seagrave hallmark. Moreover, a 'gee-whiz' enthusiasm about his subject easily infects those within range.

Dick joined the Iowa State faculty in 1966 after spending several years at Cal Tech where, in addition to teaching, he worked on oscillatory combustion under B. H. Sage. Before that he taught for one year at the University of Connecticut.

Dick's interest in a teaching career sprang largely from his association with Ray Fahien at Iowa State. Dick began his graduate studies at this school in 1957 after receiving his BS degree from the University of Rhode Island. Ray not only guided him through the rigors of turbulent flow phenomena but showed him that scholarly work could be enjoyable. Thus inspired, Dick was ready to cast himself in the academic scene upon receiving his PhD in 1961.

At Iowa State, Dick is associated with Chemical Engineering, Biomedical Engineering, and the Engineering Research Institute. He has played a key role in curriculum development and has seen to the integration of subject matter which was formerly presented in separate courses on unit operations and transport phenomena. He has developed several new courses including, "Biomedical Applications of Heat and Mass Transfer." This course led to his writing a text bearing the same title which was published recently.

Dick has attracted an outstanding group of graduate students who are working on various problems of transport phenomena in flow systems, some of course being physiological. This group is accomplishing some interesting research. For example, one of Dick's recent PhD students, M. S.

I try to find "down-to-earth" or "far-out" from earth examples to illustrate . . . principles.

Selim, developed a general method for solving moving-boundary transport problems in finite media by integral transforms.

During the past academic year Dick has served as acting chairman of the Biomedical Engineering Department while Neal Cholvin, the regular chairman, is on leave. Although this has been a heavy load on him, Dick plans to be rejuvenated at the Institute of Medical Physics in Utrecht (the Netherlands), not as a patient, but as a scholar on sabbatical starting next September. Here he plans to work with Dr. Jan Beneken on the development of an automatic control system for the administration of anesthesia and to write a textbook on physiological simulation.

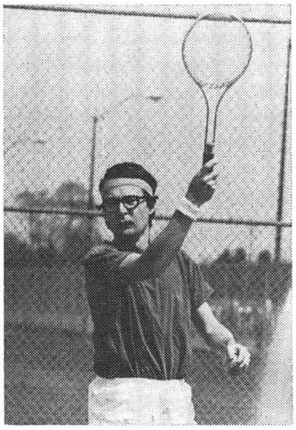
Being an American history buff, it was natural for Dick to become engrossed in politics and thereby become chairman of the Democratic Party in Story county. July will see Dick at the National Convention in Miami Beach championing favorite issues and candidates. This plus other summer activities will keep Dick moving at his usual energetic pace. In August he and Giles Cokelet from Montana State will be leading a workshop on Integration of Biomedical and Environmental Applications of Chemical Engineering into Undergraduate Courses at the ASEE sponsored Summer School for Chemical Engineering Faculty in Boulder, Colorado. Between various professional activities, Dick hopes to have a vacation with his wife, Jan, and children, John and Katherine. Since the Rocky Mountains are a favorite vacationing spot for the Seagrave family, the Boulder assignment is a fortuitous one.

Work-filled days and politics-filled evenings are hardly sufficient to consume the Seagrave energy, so extra steam has to be discharged in "tennis, basketball, and running around in circles." Then, of course, when there is nothing else to do, the neighbors can be organized for a game of touch-football. Naturally, the major professional and intercollegiate sports must be attended to and football, basketball and baseball pools organized to add zest.

Since no writer could do justice to the Seagrave personality, we taped an interview with Dick and have included some of his remarks below.

Q. Dick, why did you ever decide to become a chemical engineer?

A. I was always interested in designing and building things. In fact at one point in high school I can remember I had just about decided to become an architect, and really I guess the turning point was high school chemistry. I think that my chemistry teacher, a lady who had taught in our high school quite a while, was a very influential person in that regard. I really enjoyed (learning about chemistry) as much as anything I ever did in high school. That was kind of coupled with a very strong interest, if you can believe it, in mechanical drawing, and I used to spend all of my spare time in high school down in the mechanical drawing shop making sketches and drawing pictures and I guess a lot of that was from my previous desire to be an architect.



. . . extra steam has to be discharged in "tennis, basketball or running around in circles."

. . . it was natural for Dick to become engrossed in politics . . .

"I'm beginning to think that the engineering profession is going to need two kinds of people in large numbers . . . the technologist, a person who can perform the support functions of engineering . . . (and) people who can solve the problems that haven't come up yet."

Q. You are noted for maintaining student interest in the classroom. How do you manage to do this?

A. If there's anything I consciously do, which I think is fun for everybody to do, it is to look for application of the principles that we're talking about in what you might call unusual areas. I mean, when we talk about thermodynamics, it's just as easy to talk about the thermodynamics of people or cities as it is to talk about the thermodynamic system in a cylinder. I think that I try to find 'down to earth' or maybe 'far-out' from earth examples to illustrate a lot of these principals. When we talk about heat transfer, again it's just as easy to talk about new-born infants as it is to talk about a cast iron sphere. And, ever since I started teaching, I've tried to find what you might call homely examples. Cooking time of turkeys, a problem from Bird, Stewart and Lightfoot, is a good example. Almost everybody can stay interested in that for a half an hour and it's just as good an example of how to do heat transfer calculations as a melting block of ice.

Q. What are some of the satisfactions that you get from teaching?

A. I think the main satisfaction is helping people to become independent thinkers and teaching young people to have confidence in their ability to do things. It's particularly fun to see the transition that occurs between about the junior year of college and the second and third year of graduate school. To watch the ability to handle problems and self-confidence develop in students is enormously satisfying.

Q. When do you think you first started seriously thinking about becoming a teacher?

A. I had some twinklings about that in my third or fourth year of college as I began to near the end. I don't know, that was a very uncertain time. You know we were in high school during the Korean War and the universal military training act had just been passed and it seemed then that most of us were going to have to serve in the military service, and I don't know, I can't remember thinking a whole lot about what I was going to be doing after graduating from college. I was in advanced ROTC in college and it was assumed that I'd graduate with a commission in ROTC and serve two years in the Army, but during my senior year they had a cut-down in the level of ROTC, and it was at that point that I made a definite decision to go on to graduate school and begin thinking about what it might be like to teach. The faculty at the University of Rhode Island was really good. We had very small classes and a lot of interaction.

Q. Did your graduate advisor, Ray Fahien, influence you in such a way that you wanted to become a teacher?

A. Yes, there's absolutely no question about that. I think Ray Fahien was one of two or three most influential people that I had encountered during my life up to that time. I think that by example, he really stimulated me and many people who were in graduate school at my time. I think there were maybe ten or twelve of us during the period that I was a graduate student, who left Iowa State and went into teaching and I think all of us point to Ray as being a very influential person. It was not that he urged people to consider teaching as a career, but I think he showed us how much fun it was to be learning about new things. It was an exciting time in chemical engineering anyway because the nature of graduate work was changing. Bird, Stewart and Lightfoot's book, for example, appeared halfway through the time I was in graduate school and I look back with great pleasure to the group of us who went through that for the first time with Ray in 1960 and 1961. I think out of that class of about fifteen, six or eight of us alone are now in universities somewhere. Yes, Ray was a definite influence on me as a teacher and probably as a person.

Q. What do you feel sparked your interest in Biomedical Engineering?

A. At Cal Tech I was stimulated by Giles Cokelet, a good friend of mine, who is at Montana State University. He had done his PhD at MIT working on blood flow, rheology of blood, and he and I had some very enjoyable sessions as we began to what you might call stretch out, and think about how principles of chemical engineering could be applied to medical problems. And so I began to develop an interest in medicine and there had been times before in my post PhD period when I had seriously considered going back to school again and studying medicine. *But I felt that my expertise could be put to better use by thinking of ways that engineering could be applied to solve medical problems,* and so when the chance came to come back to Iowa State to work in the biomedical engineering area and to be a chemical engineering faculty member in a very well established graduate school, it was an easy thing for me to do.

Q. Have you found it very difficult to make the transition from chemical engineering to biomedical engineering?

A. No. I think it's been very easy, because it's so much fun and because a chemical engineer is probably better prepared to do this than any other person I can think of. A chemical engineer has all the necessary ingredients; it's a matter of putting them together and changing your vector, so to speak, heading off in a new direction. But it's been very easy and in the particular kind of atmosphere we have here at Iowa State, and the relationships we have with the Veterinary College for example have made it quite easy. There has been lots of time spent in learning new things but, you know, you're doing that anyway.

Q. What caused you to write your new book entitled "Biomedical Applications of Heat and Mass Transfer?"

A. Well, let me say that I felt that it might be fun to write down, in some formal fashion, some of the things that I had found interesting in applying chemical engineering to the study of physiology. The purpose of the book really is to sell chemical engineering more than it is biomedical engineering. Biomedical engineering is more

When we talk about heat transfer, it's just as easy to talk about new-born infants as it is to talk about a cast iron sphere.

mechanism than it is a profession and I think that it was a lot of fun to develop some of these ideas, and to write them down was an easy part of the job.

Q. What are your plans for next year?

A. When I first started at Iowa State, I never understood why people would ever want to go away for a year, why people needed sabbaticals. But, in the last year or two I have felt the need to make a fresh start on many things and I think a sabbatical year away like this can provide an opportunity to do that. Next year we are going to be at the Institute of Medical Physics in Utrecht and I want to work on a problem there. Actually, the Institute is similar in size and activity and almost in function to the biomedical engineering department here at Iowa State. In fact, there's a very strong comparison between the kind of research projects they have and what we're doing here. The difference of course is that it's purely a research type atmosphere.

Q. What problems do you think chemical engineers should turn their minds to in the future?

A. No. 1, of course, is the problem of energy sources and delivery, and I think that every chemical engineering department ought to have something going in this area. No. 2, which I feel is going to be a very big problem, and this is a lot of my biomedical engineering interest, is delivery of health care. If you live in a big city or in a rural area right now in the United States, the health care delivery is a national scandal. It is a massive engineering problem, and I think that every area of engineering, chemical engineering, biomedical engineering and all the others, must participate in working out schemes to deliver health care to all the citizens. No. 3, of course, is food. We all know about the projections which show that using current methods of technology the capacity of the earth to produce food is not sufficient *to take us through another hundred years. So we have to look for new ways to develop and process food and, of course, new ways to distribute food.* And I think the conversion of things that are on the earth's surface, for example algae, into edible, palatable food is going to be important. No. 4, of course, is what's the relationship of the earth going to be to the rest of the solar system. Chemical engineers have a lot of interesting problems that can be worked out in space travel and in design and operation and exploitation of space stations.

Q. How can we improve the education of chemical engineers?

A. Well, one of the things we've talked about at great length this year at Iowa State is the changing needs of the engineering profession. I'm beginning to think, although I wasn't sold on this concept two years ago, that the engineering profession is going to need two kinds of people in large numbers. It's going to need what you might call 'the technologist,' a person with a basic education in chemical engineering who can perform the support functions of engineering and who can go out and be a manufacturer or work in some of the more routine design areas. To produce this person, I think we really need a streamlined curriculum and teachers who have experience in these areas and we've got to think about economic production of large numbers of these people. But I think the engineering profession also is going to need fairly large numbers of people who are trained to solve the problems that haven't come up yet, people who are going to solve some of the more exotic problems that I was referring to earlier in health care delivery or space travel. So we're going to need people that have a bit more advanced training, but within the confines of an undergraduate program.

Q. You've been pretty active in the Democratic Party the last few years. What do you hope to accomplish by working in organized politics?

A. I might say at the outset that it's an educational venture. I feel that what I can learn from doing that is useful, but I also feel that people like us have something we can contribute to the political party system and to government in general. *It can provide an outlet for the strong feelings you may have on issues you think are important for your city and your state and your country.* It's a way to make your voice a little bit louder than it would be if all you did was vote on election day. It's a wonderful experience for people who normally lead a very sheltered life, in that we can come into contact with people from all different levels of society, people of different backgrounds and views. It's really a lot of fun, I think, is the main thing to say.

Q. Would you ever consider running for public office?

A. No. That's the subject that comes up all the time, I think, because people don't realize that political parties need two kinds of people to operate. They need the kind of people who are willing to make the enormous sacrifice to be candidates, and hold these positions of responsibility, but parties also need people who like to do the organizational tasks, which you might call the administrative tasks of the party, and that are willing to stuff envelopes and ring doorbells and raise money. I really enjoy those parts of the system. I have never even thought about trying to run for an office.

Q. What sort of kicks do you get from sports?

A. It's been pointed out by doctors and others that there's a certain amount of euphoria associated with all kinds of physical activity. *The good feeling that you have after a hard hour of basketball over the noon hour, or after running on the golf course in the Fall and the Spring when it's particularly pretty there, is probably perhaps psychological as well as physiological.* I guess I just feel relaxed, cleaned-out and stimulated as a result of physical activity. I don't have enough self-discipline to lift weights or to do calisthenics and I like basketball and tennis because they're just kind of fun to do.

Q. How do you explain your work to your children?

A. That's a problem I haven't solved yet. I'm not sure they think I work. They probably think, if someone would ask them, that I was probably earning my living working for the Democratic Party. From the part of my life that they see, I think that's probably a good conclusion for them to make.

Q. Do you have any hobbies we haven't discussed yet?

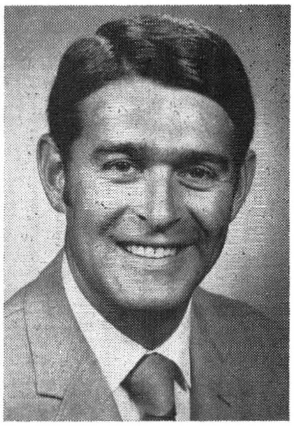
A. Well, I spend an awful lot of time reading. You might say I'm an American history buff and I enjoy keeping up with American fiction. *I manage to read most of the things that make their way to the top of the best seller lists.* I probably enjoy that most of all, although it gets increasingly harder to find time to get everything read I'd like to. □

ChE CAREER GUIDANCE AND RECRUITMENT

Editor's Note: Following are several articles that deal with the guidance of qualified students into chemical engineering. The papers by Professor Hawley, Kube, and Mischke were presented at the 1971 ASEE meeting.

Michigan State University

MARTIN C. HAWLEY
Michigan State University
East Lansing, Michigan 48823



Martin Hawley is an associate professor of chemical engineering at Michigan State University. He received his doctorate in engineering from Michigan State in 1964. His fields of specialization are reaction engineering and design.

The faculty members of the Department of Chemical Engineering at Michigan State University have been actively involved in providing high school students information on Chemical Engineering for future career decisions. The methods used for communicating this information have been a motion picture, poster mailings, special on-campus programs, personal visits, local AIChE activities, and local news media.

Career guidance and recruiting by Engineering Colleges, Chemical Engineering Departments, and faculty are necessary now days in order to partially counteract the effect of the current economic squeeze on chemical engineering enrollments and to maintain modern engineering programs; however, curriculum revisions are unlikely to have significant effects on enrollments. Unless counteracted, the publicity and impact of short range adjustments by government and industry for economic control will have long-range effects on engineering enrollments, especially if we just stand pat! It is extremely evident to those of us in the chemical engineering profession and education that chemical engineering has a significant role in solving problems (particularly of *chemical* nature) of industry and society both today and tomorrow. Further, we are all aware of the fact that modern chemical engineering programs provide a vehicle for students to achieve a high level *education* as well as prepare for a professional career.

We as educators and members of the Chemical Engineering profession recognize and understand the educational value and importance of these skills. This understanding is not necessarily shared by the public in general. One of our objectives at Michigan State University is to communicate in a responsible manner the story of chemical engineering to *young people* and the *public.*

MOTION PICTURE

The Instructional Media Center and the Chemical Engineering Department produced a 16 mm color movie with sound entitled "The Chemical Engineer." The objective of this movie is to familiarize high school students with the profession of chemical engineering. The movie describes chemical engineering, illustrates what chemical engineering *students* do, describes the type of educational program at Michigan State, and points out the diversity of career opportunities.

It took about one and one-half years to produce the film for a cost to the Chemical Engineering Department (from special grant funds) of about $4,000; however, the Instructional Media Center underwrote the cost of writing, producing, and overhead. Six copies are available in the department for circulation to high schools and interested groups.

During the academic year 1970-1971, there were 48 requests to show the movie to high school student groups. Most of these requests came from

Michigan high school counselors and students in response to a poster mailing, and from high school counselors and chemistry teachers who had previously seen this film. In some instances chemical engineering faculty members accompanied the film and were available to answer questions from the students after its showing.

POSTER MAILINGS

An attractive poster was prepared with returnable post cards attached inviting high school students to inquire about the chemical engineering program at Michigan State University. Information on the availability of our film was included on the poster. This poster was mailed to counselors and senior class presidents in approximately 900 high schools in Michigan. There were about 250 requests from this poster for information on chemical engineering. These inquiries were answered via a personal communication describing the profession, opportunities, and our program at Michigan State University along with a curriculum brochure and the AIChE pamphlet "Will You Be A Chemical Engineer?".

SPECIAL ON-CAMPUS PROGRAMS

During the spring terms of 1968 and 1971, the chemical engineering department held a one evening program for Michigan high school chemistry teachers. The objectives of these programs were to familiarize high school chemistry teachers with the chemical engineering profession, career opportunities, and our program at Michigan State.

This past year our program consisted of a dinner followed by a talk entitled "Trends and Fads" presented by H. D. Doan, former President and Chairman of the Board of Dow Chemical Company. Mr. Doan pointed out new challenges and opportunities available to chemical engineers along with increased demands. About 150 chemistry teachers attended each of these sessions and copies of Mr. Doan's talk were sent to all counselors in Michigan.

OTHER ACTIVITIES

Faculty members have cooperated with the local AIChE section (Midland, Michigan) on career guidance activities. Our Chairman, Dr. Chetrick, has appeared on local television panel discussion sessions with leaders of the chemical industry and government to inform the public of the chemical engineering profession.

Also the College of Engineering at Michigan State sponsors career guidance and recruiting activities in which we participate. Michigan State University has a very successful program for recruiting merit scholars; many of these top students over the past few years have chosen chemical engineering.

SUMMARY

During the past seven years, the number of Chemical Engineering graduates has risen from 16 in 1964 to 29 in 1971. We have had five students place in National competition of the AIChE student contest problem. It is difficult to assess the effect on enrollments of career guidance efforts. However, we believe these efforts are well worthwhile and plan to continue these types of activities. □

Motivating for ChE

WAYNE R. KUBE
University of North Dakota
Grand Forks, N.D. 58201

I assume that my comments will differ from the other speakers on the program as I have no intention of playing the numbers game. I have read too many conflicting estimates and projections, seen many of them prove to be erroneous, and I have been burnt too badly myself in making estimates to indulge in this pastime. Personally, I believe that the biggest mistake made in projections and estimates was in the number of advanced degrees required, both from the viewpoint of demand from students and the demand by organizations utilizing the graduates.

Other differences are that I will take this opportunity to air some of my personal prejudices and biases. I will also briefly discuss some of the activities of the AIChE in motivation of students to enter chemical engineering.

Actually, we as engineering educators, or more specifically chemical engineering educators, are in trouble. The image of our product has been seriously tarnished as evidenced by the decline in interest of the bright students to pursue engineering as a career. I view this as being more serious than the overall decline in percentage of high school students considering engineering careers. The present shortage of job opportunities for the

W. R. Kube received his BS and MS in Chemical Engineering from MTU at Houghton, Michigan. After service in WW II, he taught at MTU, worked in industry, and as a research ChE for the U.S. Bureau of Mines. Presently, he is Professor of Chemical Engineering at the University of North Dakota. His major interest is in low rank fuels. He is co-chairman of the Lignite Symposia, a series of technical meetings concerned with the technology and utilization of Western solid fuels. Past chairman of the National Career Guidance Committee of the AIChE, he has served on several other national committees and is a registered professional Engineer in North Dakota.

new graduates has also occurred at a most inopportune time. Lack of opportunities, coupled with the concept that engineers are responsible for the deterioration of environment, has "turned off" many from pursuing engineering careers. A recent article in *Business Week* stressed a major decline in freshman applications even at the most prestigious engineering schools. I have no way of estimating what these effects are but it is my belief that the present drying up of the student pipeline will be seriously felt four or five years from now. No one knows how long the present employment situation will last, but I believe the effect will be devastating. What we need is some way of motivating the young people into taking chemical engineering despite the present uncertainties. We have to do more to change our image than to call ourselves molecular engineers.

In considering the problem we should go back to fundamentals and consider basic questions. Let's ask ourselves these questions: **(1) Why, (2) Where, (3) When, and (4) How?**

WHY DO WE NEED CHEMICAL ENGINEERS?

This is a very fundamental question and one I have never heard a chemical engineer educator ask. However, I have heard many engineers in industry question the desirability of graduating more chemical engineers. Their philosophy is "the less, the better" as they apparently believe that they are then more certain of their position. I usually answer them by asking, "Who are you going to boss if there are no new chemical engineers coming up through the ranks?" We as educators, intuitively at least, feel the more the better and never question this feeling. This is reasonable as new students are our bread and butter, and training in the concepts of chemical engineering is good for everyone.

WHERE ARE THE NEW ENGINEERS COMING FROM?

Figure 1 shows roughly where we obtain our raw material. Obviously, the basic source is the high schools and the majority of students enter college directly from high school. Some, however, may enter at any of the four years from either having completed their service requirement, transfer from a Junior College, entering from other disciplines, or starting school after working a few years. With the emphasis on Junior or Community Colleges one would suspect that the number of junior college transfers would be an increasing source of students. However, it has been my experience that those transferring into chemical engineering never replace by numbers those who are lost by attrition. Attrition is a problem in its own right and should deserve special consideration. Why do we lose so many good students who at least at one time were interested in chemical engineering?

We should seriously look at whom we attempt to motivate into chemical engineering. Most of us, myself included, have a tendency to think in terms of proselytizing the outstanding male high school student. By not considering the feminine gender, we automatically lose a large number of possible engineers and in these days of women's

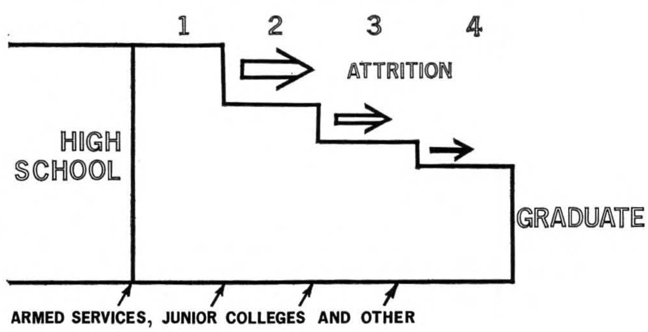


Figure 1.

lib, more women will be interested in engineering. We should also be interested in the disadvantaged and minority groups. Many of these, if properly motivated, will become good chemical engineers. I have noticed that few children of engineers become engineers. They seem to have more "relevant" career goals. Sons of the lower middle class, or blue collar workers, appear to be more motivated towards engineering, apparently as a method of improving their "station," and many do well.

By not considering the feminine gender we lose a large number of engineers.

WHEN TO MOTIVATE?

From my observations most of our attempts to interest students toward engineering, or more specifically chemical engineering, have been directed towards the seniors in high school. This is a serious limitation. Most students when they are seniors are fairly well committed towards specific goals and their selection of courses since the 9th grade has essentially committed them to a technical career.

Any recruiting efforts directed toward juniors or seniors in high school might influence a student to take chemical engineering in preference to civil, electrical, mathematics or physics but would not influence him towards a scientific career unless he had already taken the basic science and mathematics sequence. At least in our high school system the student is required to submit his four year program before entering the ninth grade. Admittedly, this is not a hidebound or unchangeable program, but very few students deviate much from the original.

If general career goals are decided before the ninth grade, this means that we must somehow motivate grade school students towards the chemistry, physics, mathematics sequence. In talking to many educators and to those in industry, I find that they have not considered the necessity of motivation in the lower grades. Personally, I feel that this is perhaps our more fruitful area.

HOW TO MOTIVATE

The question of motivation, of course, is the sixty-four thousand dollar question. Everyone has his pet ideas about this and most of these ideas work in special circumstances. There cannot be any hard or fast rules concerning approaches as it is so much a function of the personality, interest and methods of both the student and the person doing the motivation. Much discussion has been given concerning who or what motivates the young people. Actually, it is difficult to find out from students why they did choose a particular career. Most are apparently not clear themselves. From my experience I have the firm belief that in the school system the person who has most to do with selection with a scientific career is the science, chemistry or mathematics teacher. The professional counselors apparently have little influence and then mostly in selection of a specific field. Apparently the parents have very little to do with career selections. Illogically as it seems, chance remarks or comments of their peers seem to have a major influence.

All of this does not mean that the individual chemical engineering professor does not play an important role. He is very instrumental in keeping a student in chemical engineering. His kindness and personal dedication to the interest of the student and the profession is necessary and important.

I have not suggested any mechanics for motivation. The mechanics depend greatly on the special circumstances, the individual institutions, and upon personality, dedication and individual methods of the motivator. Other speakers will undoubtedly explain their methods. I will briefly talk about some of the techniques used by the National Career Guidance Committee, AIChE, rather than those at the University of North Dakota.

The National Career Guidance Committee of the Institute was established in 1952 by action of council. The boundary of its authority was established as: to provide information, counsel and leadership for Local Section Committees who are responsible for guidance for pre-high school and high school students, supplying information for high school faculties and parent groups concerning careers in science and engineering in general, and in chemical engineering in particular. It shall:

a. Develop and recommend to council the scope and basic policies of guidance activities
b. Integrate guidance committees with AIChE committees concerned with similar problems, and
c. Coordinate the Institute's guidance activities with other educational science, engineering and service organizations.

The Committee has evolved through the inter-

(Continued on page 141).

Viriginia Polytechnic Institute

ROLAND A. MISCHKE
Virginia Polytechnic Institute and State University
Blacksburg, Va. 24061

A motivational approach to recruitment.

Roland A. Mischke received his undergraduate degree from Pratt Institute (B.Ch.E. '50) and worked for six years as a design engineer with Chemical Construction Corporation before returning to graduate school. Following the completion of his graduate studies (Ph.D. Northwestern '61) he entered the teaching profession. He is currently in his ninth year at Virginia Polytechnic Institute and State University, where he has been involved in the teaching and direction of research in the fields of reaction kinetics, fluid dynamics, thermodynamics and heat transfer. In addition to his teaching responsibilities in the Chemical Engineering Department, he is also Educational Technology Coordinator for the College of Engineering.

The past few years seem to indicate that engineering as a profession is losing favor with the younger generation. Even though the anticipated needs of society for engineers continues to increase, engineering enrollments are falling. This decline then results in a more intense competition for students among the various disciplines. The situation at Virginia Polytechnic Institute may not be typical, but Figure 1 shows what is happening there. This figure shows the percentage of engineering students who elected the various major disciplines for the past ten years. Our students formally elect their curriculum at the end of the freshman year, and these figures reflect only those students who elect to remain in engineering. Since the total number of students has remained remarkably stable (between 550 and 650 students) over this time period (even though the total university enrollment has gone from 5,000 students to 12,000 students), the percentage figures are very nearly representative of actual student enrollments.

The variations in enrollment from year to year are quite erratic, but some trends are evident. If we apply some smoothing to the data in Figure 1, we obtain the trend lines shown in Figure 2. The aerospace field trends follow the emphasis and de-emphasis of government programs. The recent upswing in civil engineering can be attributed to the fact that the environmental courses at VPI are offered by a sub-discipline of civil engineering. The rise in electrical engineering enrollment is probably related to the continued and increasing emphasis on electronics, digital computers, and control systems. However, the variation in chemical engineering enrollment is both unexpected and disturbing. After all, chemical engineers are eminently qualified for work in the control and environmental areas, if they are so inclined. The root of the problem of declining enrollments must lie in our failure to make students aware of this situation before they choose their curriculum. This is the situation to which we turned our attention earlier this year.

AN APPROACH TO THE PROBLEM

Engineers are problem solvers—that is what they are trained to do. Therefore, as engineers we attempted to apply some of this engineering know-how to the analysis and solution of this enrollment problem.

The traditional approach to engineering problem solving involves: (1) definition of the problem, (2) determination of alternate approaches to a solution, (3) detailed analysis of each approach to yield a number of possible solutions, (4) choice of the best solution, and (5) implementation of the chosen solution. More modern systems approaches would include the evaluation of the implemented solution, together with feedback and revision stages.

The intent of this paper is not to consider a complete solution to the problem, but to concentrate on the problem definition and one solution approach.

Definition of the Problem. As we saw it, the drop in chemical engineering enrollment was a symptom of our failure as chemical engineers to be effective evangelists. We had failed to interest others in the broad field of chemical engineering. To start a campaign to beat the bushes with a high pressure enlistment program would only introduce a new set of problems if people not

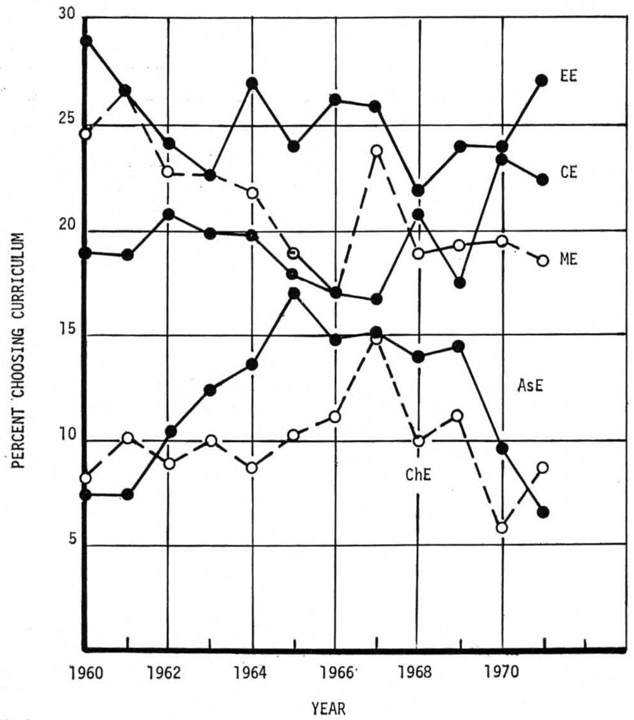


Figure 1.—Curriculum Enrollments at VPI 1960-1971.

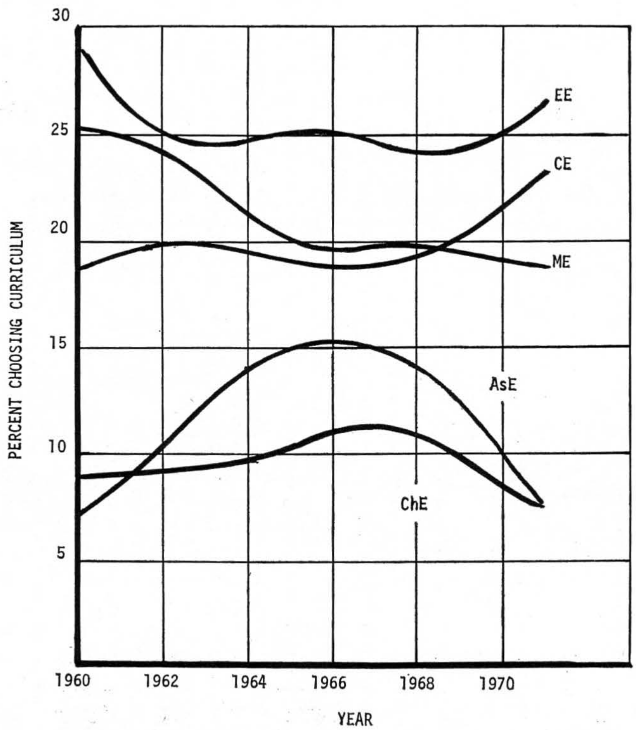


Figure 2.—Enrollment Trends at VPI 1960-1971.

. . . our approach centers around the development of a tape-slide presentation to handle the animated part of the job.

really interested in the field were lured into it. We wanted to plan a better job of selling than we are now doing, but not to the point of pressuring students into the program. Our problem statement then takes the form:

Develop programs for disseminating information about chemical engineering at the high school, junior college and university levels, so that all capable and potentially interested students are aware of the opportunities and challenges of the profession.

With a problem formulation completed, we were in a position to generate approaches to the solution of the problem. In what follows I have chosen only one approach, and I want to discuss the design background for that approach in some detail.

One Approach to a Solution. In our situation at VPI, we have the responsibility of presenting information about our curriculum to some 25 sections of engineering freshmen. It is not possible for one person to present the same program 25 times during a five or six week period and to make an enthusiastic presentation each and every time. Our approach, therefore, is to automate the heart of the presentation, and then put the person representing the department into the role of a person to answer any specific questions about chemical engineering or the chemical engineering curriculum.

This approach was chosen because it could be readily adapted for use in junior colleges around the state. We would envision sending the automated portion out first to be used as guidance material. Then, at a follow-up visit by a member of the chemical engineering department, specific questions from interested persons could be handled personally.

Therefore, our approach centers around the development of a tape-slide presentation to handle the automated part of the job.

DESIGNING A PRESENTATION

If we accept the fact that communications can be designed to persuade and to inform, then we must know something of the psychological principles we are using, just as in any engineering design we make use of our knowledge of the physical principles involved.

Modern youth are the children of prosperity. The ethic of hard work and education as being the key to a better life no longer seems to apply, as it did in our generation. In a society of affluence, emphasis on humanistic needs (both concerning the self and others) comes to the fore because the physical needs have been satisfied.

Incentives for Change. Attempts to understand what influences and motivates human behavior has occupied psychologists for many years. Unfortunately, no concrete prescriptions have been forthcoming. Numerous theories have been postulated, but substantiation of them seems quite tenuous at best. Most results have been obtained from the study of animals under very closely controlled conditions. Extrapolation to humans operating under very complicated conditions seems quite risky.

Fortunately, Birch and Veroff[1] have presented an organizational scheme which seems to coalesce most of the theories into one structural whole. They have defined seven incentive systems which operate simultaneously, and to varying degrees, in every person:

1. **Sensory Incentive** System—action is motivated as a result of sensory stimulation, i.e. taste, sight, hearing, smell, feeling.
2. **Curiosity Incentive System**—action is motivated by the desire of a person to recognize a change in the pattern of stimulation.
3. **Affiliation Incentive System**—action is motivated by an attraction to another person in order to feel reassured from the other person that the self is acceptable.
4. **Achievement Incentive System**—action is motivated by a desire to perform successfully in competition with standards of excellence or with other person's performance.
5. **Aggressive Incentive System**—action is motivated (usually in response to frustration) to intentionally injure another person; the greater the injury, the greater the incentive.
6. **Power Incentive System**—action is motivated by the desire of a person to control the forces that have power over him, i.e., to have influence on his environment.
7. **Independence Incentive System**—action is motivated by a desire to accomplish an activity without any help from others.

From this array of incentives, we can select three that seem to be the most pertinent in planning our work. The achievement motive (I did something I always wanted to do, so I am somebody), the affiliation motive (I am liked by my fellow human beings, therefore, I am somebody), and the power motive (I have control over people and events, therefore, I am somebody) seem to subsume the other motives. These three motives also work to create a feeling of self-worth in an individual, and seem to represent characteristics or drives which may be fulfilled to varying degrees within the realm of chemical engineering.

. . . the incentive system is important, but so are the particular needs of our audience.

Psychological Needs. The incentive system is important, but so are the particular needs of our audience. A presentation that neglects these needs will not be very effective. High school students and lower division college students cover a wide range of developmental status. Within this group we will probably find everything from middle adolescence to mature adult behavior represented. Probably the needs of most will be closely related to those of the senior high school student. Biehler[2] notes that the age-level characteristics of this group include:

Social Needs—
Dominated by peer group opinion and need to conform; concerned with opposite sex; trying to develop proper social role (masculine or feminine)

Emotional State—
In conflict with parents; striving for independence.

Mental State—
Trying to acquire a value system; trying to select and prepare for an occupation.

Not only are the actual needs important, but the relative strengths and priorities assigned to these needs have a bearing on how we structure our presentation. Maslow[3] has presented an ordering or hierarchy of needs in human beings. According to this theory, certain needs take precedence over others, and thus a hierarchy of needs is formed. Within this hierarchy, the lower level needs must be satisfied before the higher level needs have any significant effect on a person's actions. The hierarchy that Maslow presents is:

1. Aesthetic needs.
2. Desire to know and understand.
3. Need for self-actualization.
4. Esteem needs.
5. Love and belonging needs.
6. Safety needs.
7. Physiological needs.

It is interesting to note that the things which mean most to us as professionals (and therefore the ones we would tend to emphasize in any "selling" of our life-style) fall into the top three or four categories of this hierarchy. Note also that according to Maslow's theory, these points will be meaningless as motivators to persons who have not satisfied the lower level needs of security and belonging. From the listing of age-group characteristics previously presented, we can see that the high school and lower level college students do not have this sense of security and belonging. This line of reasoning then leads us to a realization that many career guidance activities are of questionable benefit as motivating devices.

Altering Behavior. Motivation theories assume that people act and react only in response to an incentive-reward system, and that this reward or goal may be on any of the levels of the hierarchy noted above. However, the goal or reward must exist in order for action to occur. In addition, the action taken at any given time is determined by the strongest need at that moment. Information, as such, will not cause action. Although the receipt of new information may change the relative strengths of current needs (as when told that we have forgotten to do something) and activate a different incentive system, only as information is able to activate incentive systems will it cause a change in behavior.

If our goal is to influence the behavior of students so that they choose chemical engineering as their life work, then we must show them how that life-style will satisfy *the needs they have at the moment*. If we can do that, then we may proceed to consider the satisfaction of needs which appear further up in the hierarchy.

STRUCTURING A PRESENTATION

Now let's turn our attention to the implications of these motivational theories in what we are trying to do—to show how becoming a chemical engineer can meet a person's needs.

Establishing Communication. The first and most important characteristic of any effective presentation is that it communicate with the audience. One of the most effective ways of doing this is to establish a feeling of *empathy* with the audience—to reflect back to them the feelings that they have. Many of today's youth are concerned with the environment and with humanity. By showing how chemical engineers have solved problems within the social and economic contexts of earlier times, one can show how this limited outlook has created problems for today. Then if one can show a realization that today's youth have concerns about people and the environment, and sympathy with their position, the door is open to show how the chemical engineer is attacking these problems within today's socio-economic context, and why the chemical engineer is best fitted to solve such problems. To use an overworked word, the topics then become *relevant* to the concerns of the audience.

. . . relate success . . . to emphasis on affiliation, achievement, and power . . .

Using Motivational Incentives. The success of any attempt to change behavior rests upon demonstrating the relevance of the new behavior to needs felt by the individual. Not all people have the same needs, so the presentation should appeal to several types of needs. We have previously noted that one of the overwhelming needs of youth is the need for acceptance in the social and peer group contexts. These needs are tied most closely with the affiliation motive (need for acceptance). Somewhat related to this need is the need for esteem by self and others, and daydreams or fantasies concerning later life. Quite appropriately these needs are closely related to the achievement motive (achieving self-worth by doing something in spite of obstacles). Some young people, particularly those who represent the minority groups, will see control of others as their big need. This is the power motive.

Effective use of such motivational schemes in a presentation requires us to show people receiving the rewards that these incentive systems imply while doing their jobs. This requirement is one of the basic rules of using modeling to cause a change in behavior. If you want to cause a change in behavior, then *you must show a person like a member of your audience receiving the rewards he wants to receive while doing the things you want him to do.* Television commercials are excellent examples of this approach. They depict what wonderful things happen to those people who use the sponsor's product. And they do it by showing people engaged in activities which constitute rewards for one of the incentive systems described.

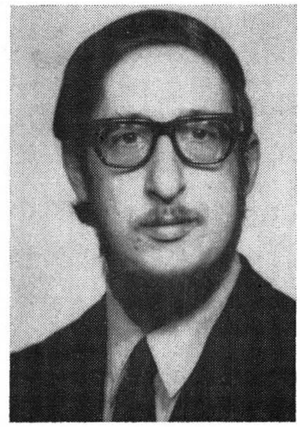
The planning and use of such motivational schemes must also be keyed to the hierarchy of needs. Going back to the age-group characteristics, we see that a prime concern of youth has to do with security, love and belonging needs. Depiction of home and community life situations which reflect the engineer achieving these goals can be quite valuable because the self-actualization needs do not become important to a person until the lower needs in the hierarchy are satisfied. Such illustrations have much more impact than the pre-

(Continued on page 140.)

"Today We Will Hear From The ChE Department"

R. M. FELDER
North Carolina State University
Raleigh, North Carolina 27607

"The lecture"— North Carolina State's "15 minute Shot at the freshmen."



Richard M. Felder did his undergraduate work at the City College of New York, and obtained his PhD ('66) at Princeton. He spent a year at A.E.R.E. Harwell, England, on a NATO Postdoctoral Fellowship, followed by two years at Brookhaven National Laboratory, and came to North Carolina State in 1969. Professor Felder's research in graduate school and immediately thereafter concerned the physics and chemistry of hot atoms; more recently, he has become involved with photo-chemical reactor analysis, radioisotope applications, and applications of engineering technology to medical and environmental problems. He has served as an industrial consultant on artificial organ development, and as a consultant to the government of Brazil on industrial applications of radioisotopes.

Once a year each engineering department at N. C. State gets a 15 minute shot at the freshmen, in which a faculty representative attempts to convince them that they would make a tragic mistake not to enroll in his department's curriculum. Several years ago, we came to the unoriginal and inescapable conclusion that boring the pants off someone is not the most effective way to convince him of anything. Coupling this conclusion with the firm belief that chemical engineering is at least as good as any other curriculum and career choice for most engineering students, we evolved The Lecture, which is given below for those who wish to pick up some of the ideas it presents, or to suggest others.

Several points are worthy of mention before the lecture commences. Two years ago, the time allotted for the departmental presentation was 50 minutes. One year ago, the time was cut to 15 minutes. Somehow or other, the same lecture has been found suitable for both time periods; the 15 minute version merely requires a slightly faster delivery, fewer side comments, and shorter pauses for laughs and breath. Many of the ideas in The Lecture were lifted from a talk given by Professor Harold Hopfenberg of our Department. Finally, in each of the past two years, the number of freshmen who chose chemical engineering at year's end was three to four time greater than the tentative (pre-Lecture) preregistration enrollment. Our rigorous background in the scientific method prohibits our drawing any causal inferences from this data; nonetheless . . . .

THE LECTURE

The usual lecture entitled "What is Chemical Engineering" is a collection of boring generalities and information which no one at your stage of the game could possibly care about. For instance,

> Chemical Engineering is an important and interesting field, in which the basic principles and techniques of chemistry, physics and mathematics are applied to industrial chemical manufacturing and processing. Here at State we have a fine department and well-rounded curriculum, which is designed to provide sufficient preparation for either an industrial career or further study in graduate school. The Chemical Engineering curriculum begins in the sophomore year with a course in basic stoichiometry, and continues with . . . . We on the faculty are eager to help you in any way we can—feel free to call on any of us at any time. Now, my first slide shows a cutaway view of a typical bubble cap distillation tower, which is a device to . . .

and so on for 45 minutes in the same sparkling vein.

Most of these things are true, but all of them are pretty much irrelevant to someone trying to make a career choice for himself. Chemical engineering is important, but so are lots of other fields. We think our department is good, but we're not the only good department in the school. Some of us are very useful people for you to meet now, knowledgeable about prerequisites and career objectives and things like that, while others of us wouldn't begin to know what to do with you if you suddenly materialized in our offices. And if we told you, for example, than in your sixth semester as a potential chemical engineer you would be required to take a course in thermodynamics, your proper reply would be "So what?"

What should we be telling you then? It might help to tell you exactly what chemical engineering is, or what you would most likely do for a living as a chemical engineer. The problem is that we really don't have a good definition of chemical engineering, and we have no idea at all what you would end up doing as a chemical engineer. If you pressed the point, we might ask what kinds of things you would like to do, and when you told us we would say that they're probably what you'll be doing if you still feel the same way in four years, which you probably won't.

Incidentally, questions like "What do chemical (and civil and mechanical and electrical) engineers do" are precisely the kind of questions you should be asking now, and probably aren't. According to our unofficial statistics, 1% of you are in engineering school because you studied the alternatives and concluded that you were born to be engineers, 13% are here because your fathers or somebody had the idea that you should be engineers, 23% because someone told you that engineers earn more money than anyone else, and the remaining 63% because English and history are a drag and pure science and math are too hard, so what else is there?

You're going to keep doing the same thing, too, if past history is any guide. "I don't like Chemistry 101—I'd better not go into chemical engineering." "Physics 205 is too tough—better forget engineering mechanics and electrical engineering." Eventually you back into one field or another, go through four years, get a job and maybe then realize that while there's nothing about your job that you hate, there's nothing much to like about it, either, and that what you'd really like to be doing is . . . . Unfortunately, by then it's usually too late: one man in a hundred is sufficiently motivated to switch fields completely after he gets out of college. The time to start thinking about what you'd like to do is now, and if you make your decisions on the basis of how you like one or another of your freshman courses, you're blowing it, and you deserve whatever you get. (Incidentally, Chemistry 101 has almost nothing to do with chemical engineering.)

All right, what do you want to do? You don't know, probably, Let's throw out a few suggestions, then—call it games chemical engineers play.

THINKING ABOUT GOVERNMENT WORK?

Become a chemical engineer and join the CIA, and diagnose aerial reconnaissance photos of chemical plant facilities in Russia or China or whoever the bad guys are at the moment, or talk to visiting bad guy chemical engineers and subtly extract useful information from them.

. . . we came to the unoriginal and unmistakable conclusion that boring the pants off someone is not the most effective way to convince him of anything.

INTERESTED IN THE HUMAN BODY?

Become a chemical engineer, specializing in biomedical applications. Things like the heart, lungs, kidneys, and blood circulation are biological analogs of the kinds of things chemical engineers have always dealt with and chemical engineers have consequently been among the leaders in the development of artificial organs and physiological systems. The application of engineering principles to the design of a device to remove wastes from blood when the kidneys fail, for example, is something for which a chemical engineer is trained and a physician is not.

ENVIRONMENTAL PROBLEMS CONCERN YOU?

There are several ways to attack the problem of a pollutant being released into the air, or into a river or lake. You can (a) treat the pollutant in some way to make it less offensive (a chemical reaction approach), or (b) separate the pollutant from the harmless stuff it's being carried along with, and dispose of it separately in a nonpolluting way (a material separation approach), or (c) arrange conditions so that the pollutant is dispersed in such a way that its harmfulness is eliminated or minimized (a transport phenomenological approach). Several branches of engineering deal with one or another of the techniques needs to implement these approaches; chemical engineering deals with all of them.

HOW ABOUT NAPALM PRODUCTION, AND SUCH THINGS?

You can go either way. If you think that this is the kind of thing you'd like to do, then go to work for the company that does it and do it; if you don't think much of the idea, tell that company exactly why you have no intention of working for them. (Talk about your effective protests!)

MANAGEMENT, FINANCE, LAW?

Become a chemical engineer, and move into production, research, or design supervision, or go to work for a firm that specializes in chemical industry venture appraisal, or go into patent law.

SCIENCE AND MATHEMATICS?

Some chemical engineers are indistinguishable from pure scientists and applied mathematicians, except that the engineers are a little more likely to wonder occasionally about the short range applicability of whatever they're doing.

LAST, BUT

far from least, you can go to work in one of many capacities within the chemical (or petroleum or plastics or pulp and paper or textile) industry, which is what all chemical engineers used to do and most still do, although there are many excellent chemical engineers who become ill within 20 miles of a chemical plant, downwind at any rate.

Notice the variety of possibilities just listed, and the list is by no means exhaustive. Also notice the responsibility—you decide for yourself whether to make napalm or artificial kidneys!

Since, as we have indicated, most chemical engineers end up in industry, it might be instructive to consider industrial chemical engineering games in greater detail. It all starts in a laboratory, when an enterprising research and development engineer discovery a reaction that gives you something valuable from something not as valuable. Let's say our man discovers that if you combine a grain, say corn, a sugar, and a bacterial agent, say yeast, a reaction called fermentation occurs, and if you boil the resulting mixture in a device known as a distillation column, or still, the part that comes off as a vapor and is then condensed has some very interesting properties.

Next comes an engineer who lays out a stepwise procedure for carrying out the new process on a large scale. He might propose something like taking the corn, sugar and yeast, and allowing them to ferment in a tank for 7 to 14 days; the tank should be buried in a field or located well back in the woods, since the reaction is easily disturbed by outside agents. The wet mash is then put through a separation unit, the liquid skimmed off the top is boiled in a still, and the vapor is condensed in a cooling coil. The liquid that comes out is known as the raw product, which is no exaggeration at all. The product may be sold as it is, or subjected to an adsorption step on charcoal beds to increase its purity, so that it may be sold at a higher price. The creative process engineer also notes that the economics of the process may be improved by taking the mash residue and selling it as hog feed instead of throwing it away.

. . . There's no better field than chemical engineering for keeping your options open.

This is an excellent example of a chemical engineering problem. You have to deal with the movement of material from one unit to another (fluid flow), supplying heat to a still (heat transfer), chemical reactions (unit processes), separation processes, such as skimming, distillation, and adsorption (unit operations), quality control, economics, etc. This is not to say that someone who isn't a chemical engineer can't do things like this—it's just much easier if you are one. The same applies to everything else mentioned here: a chemist or a physician who is particularly ambitious may be able to teach himself enough to be able to design a heart-lung device, but the things he would need to know are the things chemical engineers are taught as a matter of course.

Returning to the process, another chemical engineer calculates the size and construction materials of the process units and pipes in the system, and estimates the costs; another trained in market analysis determines whether or not it will pay to do the whole thing; another engineer lays out the plant and supervises its construction; another supervises the plant operation and sees to it that his product meets his customers' requirements; another sells the product (which may also be process equipment or instrumentation), and still another runs the show and becomes rich. Finally, some who are unsuited to any of these functions go into teaching chemical engineering.

Again, consider the variety of occupations, some of which we haven't yet mentioned: chemistry, mathematics, biology, medicine, spying, pollution control, industrial research, academic research, law, banking, weapons development, automation, economics, teaching, inventing, building, producing, selling, supervising people who invent, build, produce and sell, experimentation, theory, and on into the night. If any of these things appeals to you, you might consider chemical engineering as a career, and equally important, if you're still not sure which way you want to go, there's no better field than chemical engineering for keeping your options open. □

STANFORD (from p. 105)

hot. The energy accommodation was as low as ten percent in some cases.

DAVID M. MASON — Applied Chemical Kinetics Laboratory

Our group is engaged in research directed at a better understanding of the physical and chemical processes underlying combustion, direct energy conversion, and industrial reactions.

Heat Transfer in Reacting Systems — We are currently investigating the role chemical kinetics plays in the transfer of heat, mass and momentum in flowing fluids. With fast, exothermic reactions, unusually large heat-transfer rates can occur in such devices as chemical reactors, rocket chambers, and space-vehicles undergoing aerodynamic heating upon re-entry.

Oscillating Chemical Reactions — The mechanism of oscillating chemical reactions is being investigated with the sodium dithionite reaction in aqueous solution as the experimental model. An electron-spin-resonance spectrometer is available to detect possible oscillations in the concentration of free radicals that are present in this system.

Effect of Pressure on Reaction Rate Coefficients — The effect of very high pressure in increasing the rate coefficients of gaseous chemical reactions is being studied in an attempt to be able to predict in general pressure effects in reactions of industrial importance.

Fuel-cell Electrode Kinetics — The rate and detailed chemistry of the oxidation of hydrocarbon fuels at electrodes are a central problem in the generation of electrical energy by oxidizing readily available hydrocarbons on inexpensive electrode-catalysts at room temperature. With fuels like hydrogen and methanol, platinum is currently the best electrode material as far as giving sufficiently high reaction rates for practical use. We are attempting to learn more about the nature of electrocatalytic processes with selected hydrocarbons with the hope that a less expensive catalyst can be found for use in practical devices.

CHANNING R. ROBERTSON — Biomechanics and Environmental Sciences Laboratory

The objectives of the research program in this laboratory have a dual nature. One aspect of our work deals with the application of basic transport theories to biological systems, whereas the other stresses the use of these same theories in obtaining a better understanding of man's effect on the biosphere. A unique feature of this work is its interdisciplinary nature.

Biomechanics — In recent years engineers have been playing an ever increasing role in providing original and unique insight into the functioning of the human body. At Stanford we have established the Stanford-Ames Biomechanics Group to bring together the combined talents of people from several departments, Applied Mechanics, Aeronautics and Astronautics, Electrical Engineering, and Chemical Engineering. In addition, scientists from the Ames Research Center of the National Aeronautics and Space Administration and faculty from the Stanford Medical Center are also participating in the joint effort.

The primary goal of this research is to increase our knowledge of bodily processes which will then result in new and improved diagnostic techniques and prosthetic devices.

Our laboratory is planning to conduct studies in the area of hemodynamics, in particular, blood flow through pumps and valves. Important unsolved problems include wall-erythrocyte interactions which are thought to be fundamental to the formation of thromboses.

Environmental Sciences — It is a simple fact that no living system can survive in its own waste, and largely because of this, many researchers in various fields of specialization have turned their attention to seeking new ways of preventing further deterioration of our biosphere. The effort in this laboratory is focused on obtaining new knowledge about mechanisms of dispersion and transport of pollutants in the atmosphere, river systems, lakes, and oceans.

DOUGLASS J. WILDE — Optimization and Control Group

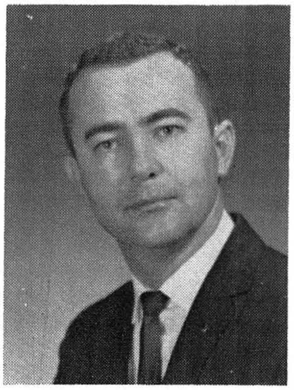
This group is engaged not only in establishing fundamental, rigorous principles in optimization, but also in applying these concepts to large, complicated industrial systems of economic and social importance. Optimization theory involves the mathematics of achieving economic minima or maxima.

Current theoretical work in optimization involves generalized polynomial optimization, direct elimination optimum-seeking methods, combinatorial optimization and optimization under uncertainty. □

CAREER GUIDANCE COMMITTEE

$$\int_{\text{Jan 71}}^{\text{Dec 71}} f(\text{Career Guidance})\, d\text{CG}$$

WALLACE HLADKY
Salsbury Laboratories
Charles City, Iowa 50616



Wallace Hladky is Manager of the ChE Department and supervises the Environmental Services Department of Salsbury Laboratories, Charles City, Iowa, a manufacturer of animal health products and organic chemicals.

Mr. Hladky received his BSChE from Iowa State University in 1950. In addition to other appointments, he served as Career Guidance Chairman of the Iowa Section of AIChE, was advanced to National Vice Chairman in 1966 and was appointed Chairman in 1969.

"What right have you to guide students into Chemical Engineering when I'm out of a job. Whose side is AIChE on?" And,

"I'm sorry I can't make the meeting. My company has cut back and I'm swamped with work. And my travel budget has been cut."

Each of the above statements has been made to this Chairman this past year—the first one, twice; the second, many times. I do not believe a high percentage of our members advocate suspension of guidance activities because of the job market. However, for those out of work, a serious situation exists and such thinking is understandable.

Possibly my loyalty to this committee colors my thinking. However, my contention is that guidance activities should continue for the following reasons.

- **First, a cessation of guidance activities would not significantly reduce the output of chemical engineers for five or six years. Those already "in the mill" will continue to graduate. This time lag between career decision and actual graduation points up that in order to assist the currently unemployed, guidance activities should have ceased in 1967 or 1968—a time when frantic recruitment caused spiraling wage offers and, in itself, was a lure to the engineering profession.**
- **Secondly, mere replacement of those who retire, die, and otherwise attrition themselves from the profession, dictates a minimum number of graduates each year to keep our profession alive. I estimate this number to be approximately 3000 graduates.**
- **Finally, any high school senior has the right to information which assists him in making a career decision. And this includes data on employment and unemployment. More, we hope this minimum number of graduates will be those of high caliber.**

Admittedly, our AIChE guidance effort is composed of a variety of volunteer workers, and, depending upon the degree of training in this work, sometimes it takes on an attitude of recruitment. This is not intended. Our philosophy is to pass on to the student unbiased information so that he can make an informed decision.

A TAR-BABY ECONOMY

Hard core economy is a sticky monster which quickly traps volunteer activities and expenditures. Travel funds, secretarial time, postage and duplication expense as well as basic "time available" for the career guidance committee members fell prey this year. As a result, a general reduction in progress was noted in this committee.

PROGRESS ON SOME FRONTS

"Tell me how to get rolling!" many newly appointed Local Section Career Guidance Chairmen write. To assist them, Mr. Howard Phillips has developed a portfolio with visual aids, bibliographies, and job descriptions. Mr. Galluzzo's Career Guidance Manuel for Chemical Engineers is included. The draft is now in the hands of National whose job it is to proof, type, and distribute the copies via our liaison system to the above-named chairmen. The liaison system of the Committee is being organized by Mr. Henry Brown, Chairman of the Subcommittee on disadvantaged youth and will serve the needs of

. . . What right have you to guide students into chemical engineering when I'm out of a job?

the full Committee as well. That is, if the liaison can find out the name and address of the local section contact.

WHICH BRINGS US TO

A complaint of mine: I, and others, have requested that National mandate all Local Sections to standardize their fiscal and officer year. Whether it is January to December or September to August matters not. But as things now stand, maintaining an accurate accounting of section representatives is a Chairman's greatest challenge. C'mon, National, let's whip this out.

THE BROCHURE IS COMING

A dedication to excellence led this Task Force to scrap the text, layout, and art work of the previous version. A professional consultant has developed a new text. The proof is now being coordinated with graphics. As a result, the new official Institute brochure should be available in quantity for the next school year. An announcement of this John Anderson-Ed Weihenmayer product will be made in *Chemical Engineering Progress.*

OH YES, THE FILM

We know it's not perfect, but it's better. The length of our film The Chemical Engineer was reduced from 26 to 19 minutes. The film was an excellent film for the public mood at the time it was developed. But moods change and the improvement in running time was effected by deleting scenes that student critics suggested. It is now available for rent or purchase from National. It is recommended that work on a new film be authorized and initiated.

CAREER GUIDANCE FOR DISADVANTAGED YOUTH

Someone said a piano is a perfect example of black and whites working in harmony. This career guidance subcommittee is composed of black and white chemical engineers. Together, they have developed a portfolio—a program of action for Local Sections. Although the program must necessarily vary with each location, the common theme is "In order to achieve success, lose yeur identity." Work with and through organizations which are trusted by the majority of the minority. To date, fifteen Sections of AIChE have active programs. Mr. Henry Brown of Squibb Institute is Chairman of this subcommittee for 1972.

HAIL TO THE CHIEF

John Zimmerman, U.S. Steel Corporation, Pittsburgh, is the new Career Guidance Committee Chairman for 1972. Give him your support. He will be up to his elbows in issues and projects. To mention a few: Development of a slide library; documenting a chemical engineer's life after graduation; utilizing video tape potential; presenting programs at national meetings; and modernizing outmoded visual aids. He will also influence decisions in other AIChE committeees through the Education Activities Coordinating Board—a Board composed of Chairmen of allied committees.

Burma Shave
Remember the road-side signs that went—

Spring has Sprung
the grass has riz.
Where last Year's
careless driver is.

As for Career Guidance and youth, we might say—

Our yesterday world
is a helluva mess.
Their tomorrow world
is a helluva guess.

Wallace Hladky, Chairman
Career Guidance Committee
American Institute of Chemical Engineers

The Career Guidance Committee of AIChE was ordered and initiated in 1952 by Council. The Committee consists of a Chairman, appointed by Council; other Committee members as the Chairman may appoint; and usually, the Local Section Chairman of Career Guidance.
The goal of the Committee is to assist the Local Sections in implementing the career guidance interests of AIChE with students, teachers, counselors, parents, the public, and allied organizations.
In 1968 the Sub-Committee on Career Guidance for Disadvantaged Youth was initiated to expedite the activities special to this interest.

STOICHIOMETRY OF A CITY

CHARLES A. WALKER and
W. N. DELGASS
Yale University
New Haven, Conn. 06520

DURING THE FALL terms of 1970 and 1971 we have offered an undergraduate course which is described as follows in the course catalog:

> **E&AS 93a, MATERIAL AND ENERGY BALANCES IN A CITY.**
> **The city will be considered as a chemical process. A materials flowsheet of input items (water, air, food, fuels, etc.) and output items (water-borne wastes, air-borne wastes, solid wastes, etc.) will be developed by the class and used as the basis for calculating the energy balance. The engineering and economic aspects of this view of a city will be discussed and applied to the evaluation of some present and alternative technological practices affecting cities. Open to juniors and seniors with Chemistry 10a and 15b, this course is intended for students whose interests are not primarily technical.**

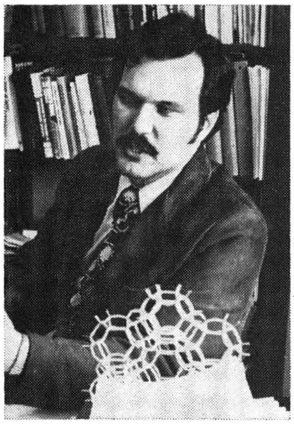
The course met for two 75-minute sessions per week. Class discussions were devoted to the principles of the stoichiometry of combustion processes, basic thermodynamics relating to energy conversion, and some basic principles of the quality control and chemistry of water and air. The American Chemical Society's "Cleaning Our Environment: The Chemical Basis for Action" served as a textbook and was supplemented by various government bulletins and articles from periodicals. Each student in the course was expected to be responsible for acquiring some of the data needed for the flowsheet, to participate in the calculations leading to the flowsheet, and to write a term paper on some topic related to urban environmental quality control.

During the two terms that the course has been offered it attracted a total of about 35 students. Interestingly, nearly half of them were majors in engineering and applied science who apparently wanted a view of engineering in a rather direct and practical problem involving a host of political, social, emotional and economic considerations. The rest of the students came from various majors in Yale College. Most of the students seemed particularly interested in the details of how processes and devices work. Teaching a class of this composition presents some interesting challenges for teachers of engineering. (If such a course were offered in a school where it attracted a larger enrollment it might be advisable to have two instructors, one an engineer and the other an economist or political scientist or sociologist.)

It was interesting indeed to hear students recount their experiences in acquiring data when they presented their results in class for use by other students and for comments and criticism. Their visits to wholesale food markets, the water company, fuel distributors, the power plant, a sewage treatment plant, the refuse incinerator, junk yards, etc., represented new experiences for most of them. The combination of one such site visit, reports of other students, and the calculation of a flowsheet has one very important result. Even the most starry-eyed environmentalists begin to recognize the magnitude of the efforts that will be required for significant improvements in the quality of urban environments. Furthermore, it is to be hoped that they learn that getting the facts in order is a good way to approach any problem.

THERE HAS BEEN another interesting result of the course, one which was not really expected. Various New Haven City agencies and environmental action groups have requested copies of the final report and seem to be finding the flowsheet useful for orientation to urban environmental problems.

There is, however, a significant flaw in a course of this type. It is an interesting course to be involved in the first time it is offered because



Professor Walker received his BS and MS degrees in Chemical Engineering from the University of Texas and his DEng degree from Yale. A member of the Yale faculty for 30 years, he has had continuing responsibilities in chemical engineering and has also served as a residential college master, director of an undergraduate major in combined sciences, and staff member in Yale's Institution for Social and Policy Studies. He is currently Chairman of the American Chemical Society's Petroleum Research Fund Advisory Board. (right)

W. N. Delgass did his doctoral work at Stanford University under Professor Michel Boudart. He joined the Yale Faculty as an Assistant Professor in 1969 after a postdoctoral year at the University of California, Berkeley. His principal research interest is the study of heterogeneous catalysis by Mössbauer and X-ray photoelectron spectroscopy. (left photo)

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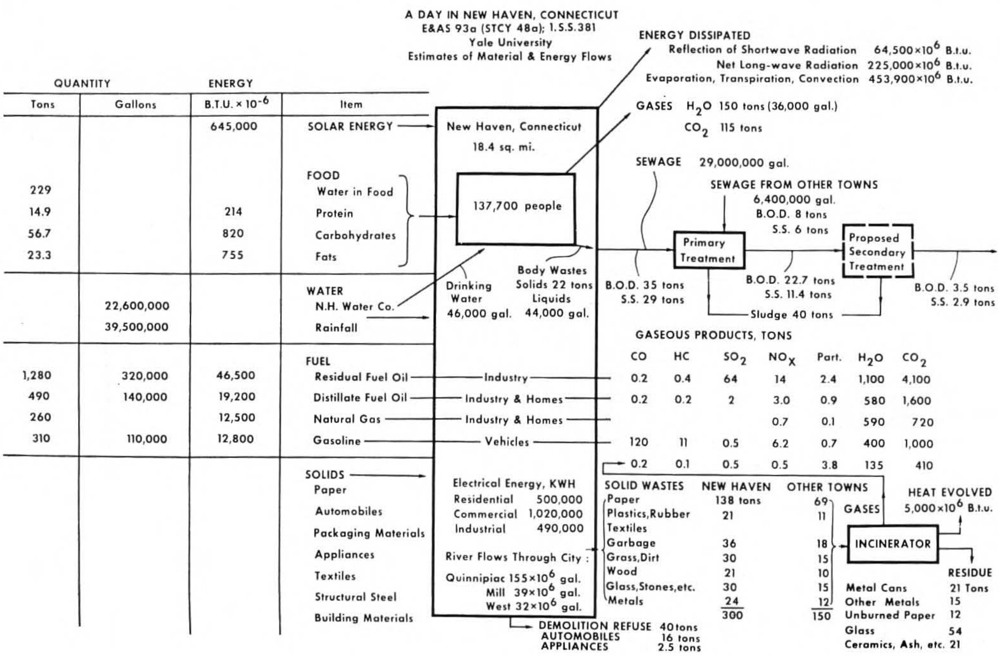
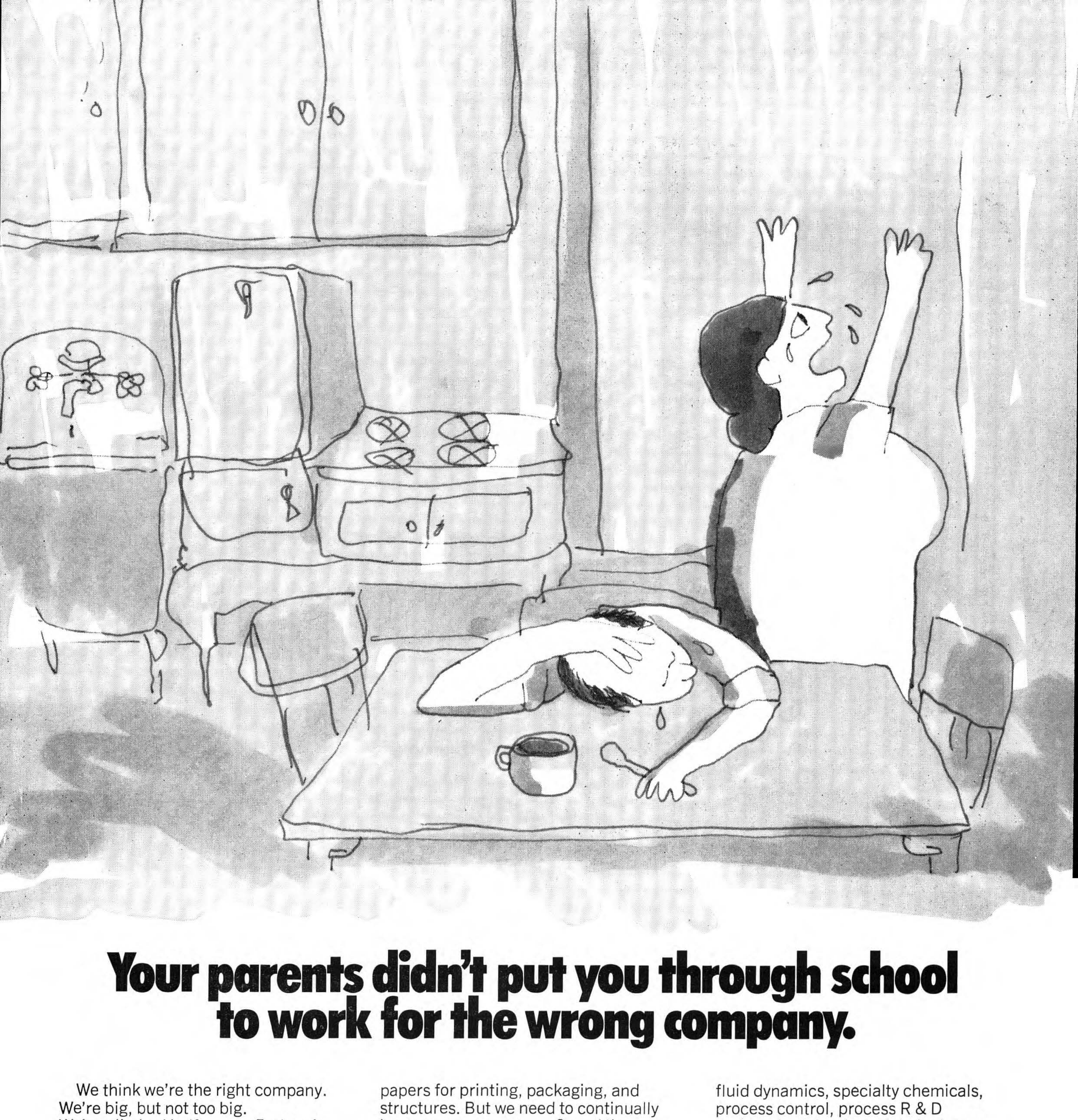
there is a sense of anticipation as to how the flowsheet will look. The second time it is offered there is an opportunity to improve the quality of the data and to include factors not considered by the first group of students. This can continue, of course, by considering variations in time and and space rather than just the steady state and perhaps by using a computer to handle a more detailed model. Such approaches are entirely feasible if a class consists primarily of students in engineering and science, but the course would not then be expected to attract a general audience. Another approach would be simply to use the flowsheet developed by the first groups in the course as a basis for a course and substitute plant visits and problems for the original data collection and calculation activities. Such a course could be readily developed into an interesting Introduction to Chemical Engineering. It is not intended to offer E&AS 93a again at Yale because a new sequence of three term courses in environmental quality control is becoming available in 1972 - 73.

REACTION TO THE course is indicated by the following critique prepared by students on the basis of the 1970 course, when it was taught by C.A.W. A critique of the 1971 course, taught by W.N.D., is not yet available. It is expected by C.A.W. to be kinder; W.N.D. won't commit himself on this matter.

E&AS 93a set out to analyze the city as a chemical process. This new and comprehensive view of a city's energy and material demands tries to tie together a





Your parents didn't put you through school to work for the wrong company.

We think we're the right company. We're big, but not too big. We've climbed halfway up *Fortune's* Directory of 500 Largest Corporations. But compare the share of sales that paper companies plow back into research. Suddenly, we're no less than second.

What does this mean when you're considering a career in paper production? It means that production engineering at Westvaco is influenced by continuous research feedback. It means lots of development work. Diversification. Excitement. Research has given us processes and equipment to make better papers for printing, packaging, and structures. But we need to continually improve our processes. Speed them up. Make them more efficient. That's your job.

Research has given us useful by-products, too. High-grade specialty chemicals for coatings, pharmaceuticals, inks and waxes. And activated carbon adsorbents and systems to alleviate water pollution. But we need good engineers to recover these by-products more efficiently. To improve them. To find new uses for them.

In our company, working with paper and paper by-products can mean good careers in design engineering, fluid dynamics, specialty chemicals, process control, process R & D and product development. And more. Chances are, whatever you liked and did best in college, we're doing right now. And doing it well.

But find out for yourself. See our campus representative, or contact Andy Anderson, Westvaco, 299 Park Avenue, New York 10017.

Remember, all your parents want for you is the best of everything. The least you could do is join the right company.

Westvāco

An equal opportunity employer

number of diverse subjects. Although a great deal of interesting material was presented, the goal of an overall perspective was never fully reached.

Much of the course dealt with the waste products of an industrial city and the technology available to remove them. Mr. Walker had to deliver his lectures to a class with backgrounds ranging from a little high school chemistry to a major in science; he handled this problem remarkably well. The lectures were generally informative and frequently very interesting, particularly when he included anecdotes from his personal experience. However, several classes weekly would have been more appropriate than the single two-hour class session.

The readings were a source of added information but did not play a major role in the course. Of greater importance was the gathering of data on inputs and outputs of the city. Small groups were responsible for each area. Toward the end of the term, each group assembled a flow sheet of the data. This was the goal of the course, but its importance seems to have been lost along the way. Ultimately, therefore, the term paper represented most of the work in the course. It gave an opportunity to look deeply at one specific area of a city and its material problems. Despite a knowledgeable and interesting lecturer and an important subject, the course never really pulled the loose ends together.

. . . the most starry-eyed environmentalists begin to recognize the magnitude of the efforts required for significant improvements in the quality of urban environments.

It seems clear that creating the flow sheet at the start would have given the class the needed perspective. This would have provided a much better context in which to judge the different economic and technological alternatives open to a city. The course was an ambitious experiment that met with some success. With better structuring and more rigor, it could be outstanding.

Several of the suggestions made by the students were adopted when the course was offered for the second time.

Further details on data and calculations are available from the author.

ACKNOWLEDGMENT

The flowsheet shown here was developed by two graduate students, John Pestle of Yale and Laurence Walker of M.I.T., during the summer of 1971 after some additional information became available. It is quite similar to the flowsheet developed by undergraduates in the fall term of 1970. ☐

ChE book reviews

Polymer Science and Engineering, D. J. Williams, Prentice-Hall, Englewood Cliffs, N.J. (1972), 401 pp.

One of the peculiar difficulties in writing an introductory textbook on polymers is the diversity of subjects to be covered, each built upon distinctly separate fields of science. Thus, the subject of polymerization has its roots in the reactions and structural analysis of organic chemistry, solution behavior in regular solution theory, rubber elasticity theory in statistical mechanics, polymer morphology and properties in the techniques of solid state physics and rheology in continuum mechanics. Scattered throughout are various applications of probability theory, and superimposed is the need to relate these principles to the practical properties of polymer systems. No single undergraduate curriculum does justice to more than a fraction of these fields. If a book of reasonable length is to be aimed at both chemical engineers and materials scientists, it becomes necessary to compromise, either by including brief introductions to the fields and showing how they apply to polymers, or by leaving out some subjects entirely and concentrating on the relationships between those aspects which are retained. In the former there tends to be oversimplification and a loss of coherence among the parts; in the latter the result is less than a comprehensive coverage.

Dr. Williams has chosen to follow the second course, and has done so rather successfully. The book is intended for seniors and beginning graduate students in chemistry, chemical engineering and materials science. It opens with an extended

(Continued on page 131.)

ChE classroom

A Unified Approach

TURBULENT TRANSFER PROCESSES

G. D. FULFORD* and
D. C. T. PEI
University of Waterloo
Waterloo, Ontario, Canada

In studying heat and mass transfer in flowing fluid systems it is often helpful to use a unified approach to stress the analogies and similarities which exist among the transfers of heat, mass and momentum. Although transfer processes in turbulent fluid streams are of great practical importance, only the simplest cases can be dealt with theoretically at present by means of the statistical approach to the study of turbulence, and even in these cases, the unified attack has not been used systematically. Often the topic of turbulence is treated as though it affects only the fluid-mechanical aspects of a problem, and the concomitant heat and mass transfer effects, which are of particular chemical engineering interest, are not stressed.

In this note we will attempt to show by considering a simple case that the unified approach can be readily and conveniently applied to the study of turbulent transfer processes. A general equation is derived describing the dynamic propagation behavior of the dimensionless Eulerian double correlation parameter for the turbulent fluctuating parts of a transferred intensive property at two neighboring points in an incompressible isotropic turbulent fluid field. From this, it is shown that the well-known von Kármán-Howarth and Corrsin equations fall out directly as special cases when the intensive property is assumed to be momentum, heat energy, or mass of a component per unit volume of the system. Although no new results are obtained, and although turbulent transfer processes are rarely encountered under isotropic conditions in practice, it is felt that the generalization is of interest from a pedagogical viewpoint as an illustration of the unified approach, which obviously can also be applied usefully in the more "practical" phenomenological approach to the study of turbulent transfer processes.

*Present Address: Hope, Spur Tree P.O., Jamaica, West Indies.

Relative to a stationary Cartesian coordinate system, the general equation expressing the conservation of an intensive property of instantaneous concentration P (i.e., P is the quantity of property per unit volume of system at any instant, and has a time-averaged part $\bar{\bar{P}}$ and a turbulent fluctuating part P′) may be expressed for a turbulent fluid as (1):

$$\frac{\partial P}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(v_j P) = - \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(\pi_j) - \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(F_j) + G \qquad (1)$$

If the time-averaged values of the property concentration $\bar{\bar{P}}$, the molecular flux of the property $\bar{\bar{\pi}}$ the velocity vector $\bar{\bar{\underline{v}}}$, and the rates of generation of the property at the surfaces and within the bulk of an element of the fluid, $\bar{\bar{F}}$ and $\bar{\bar{G}}$ are assumed to be zero, so that isotropic fluctuations relative to a zero base are considered, as is customary, the conservation equation becomes:

$$\frac{\partial P'}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(v'_j P') = - \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(\pi'_j) - \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(F'_j) + G' \qquad (2)$$

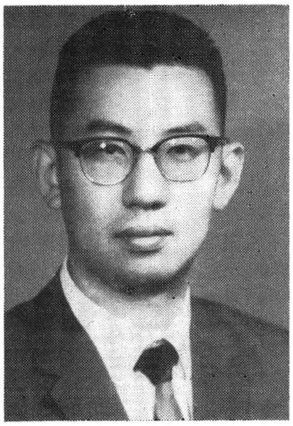
If secondary molecular transfer processes (such as those due to the Dufour and Soret effects) are ignored (*), the flux π' can be written in terms of the gradient of the concentration P′ and a generalized isotropic molecular kinematic transfer property M (assumed constant):

$$\pi'_j = - M \frac{\partial}{\partial x_j}(P') \qquad (3)$$

and equation (2) becomes:

$$\frac{\partial P'}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(v'_j P') = M \sum_{j=1}^{3} \frac{\partial^2 P'}{\partial x_j^2} - \sum_{j=1}^{3} \frac{\partial}{\partial x_j}(F'_j) + G' \qquad (4)$$

* Note that this restriction is not very clearly stated in the usual treatments of turbulent transfer processes.



George D. Fulford is Senior Project Engineer with Alumina Partners of Jamaica. George grew up in Jamaica and earned the BSc and PhD ('62) at University of Birmingham, England. His experience includes several years with DuPont in photo products and three years teaching at University of Waterloo, Ontario with special interest in the area of transfer processes. He is a member of AIChE and IChE, London and is a registered professional engineer in Ontario. (left photo)

David C. T. Pei obtained his education at McGill University, finishing in 1961. He is a member of AIChE and CSChE and is currently serving as Associate Chairman of the Chemical Engineering Department at Waterloo. His teaching interests include Fundamentals and Applications of Momentum, Heat and Mass Transport Processes. (right photo)

Equation (4) is now written for a point A in the fluid by placing a subscript A on the various quantities, and the resulting equation is multiplied throughout by the value of the fluctuating concentration P'_B at the same instant at a point B distant $\underline{r}$ from A; equation (4) is also written for point B (subscript B on quantities) and multiplied throughout by the fluctuating concentration P'_A at A **. Bearing in mind that P'_B is not a function of x_A, nor is P'_A a function of x_B, though both are functions of time, we obtain

$$P'_B \frac{\partial P'_A}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_{jA}}(v'_{jA}P'_A P'_B) = M \sum_{j=1}^{3} \frac{\partial^2 (P'_A P'_B)}{\partial x_{jA}^2} - \sum_{j=1}^{3} \frac{\partial (F'_{jA}P'_B)}{\partial x_{jA}} + P'_B G'_A \qquad (5)$$

$$P'_A \frac{\partial P'_B}{\partial t} + \sum_{j=1}^{3} \frac{\partial}{\partial x_{jB}}(v'_{jB}P'_B P'_A) = M \sum_{j=1}^{3} \frac{\partial^2 (P'_B P'_A)}{\partial x_{jB}^2} - \sum_{j=1}^{3} \frac{\partial (F'_{jB}P'_A)}{\partial x_{jB}} + P'_A G'_B \qquad (6)$$

The distance vector $\underline{r}$ between the points A and B is now written as

with
$$\underline{r} = \delta_i + \delta_j + \delta_k \qquad (7)$$
$$\delta_i = x_{iB} - x_{iA}\text{ , etc.}$$

** When P is a vector quantity, the i-component of the equation (4) at A is multiplied by P'_{kB} and the k-component of the equation at B is multiplied by P'_{iA}.

Hence,

$$\frac{\partial}{\partial \delta_i} = -\frac{\partial}{\partial x_{iA}} = \frac{\partial}{\partial x_{iB}}; \quad \frac{\partial^2}{\partial \delta_i^2} = \frac{\partial^2}{\partial x_{iA}^2} = \frac{\partial^2}{\partial x_{iB}^2} \qquad (8)$$

Using these definitions, equations (5) and (6) are added and the sum is then time-averaged to give

$$\underbrace{\frac{\partial}{\partial t}(\overline{P'_A P'_B})}_{(I)} + \underbrace{\sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(\overline{v'_{jB}P'_B P'_A} - \overline{v'_{jA}P'_A P'_B})}_{(II)} = \underbrace{2M \sum_{j=1}^{3} \frac{\partial^2}{\partial \delta_j^2}(\overline{P'_A P'_B})}_{(III)} +$$
$$- \underbrace{\sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(\overline{F'_{jB}P'_A} - \overline{F'_{jA}P'_B})}_{(IV)} + \underbrace{(\overline{P'_B G'_A} + \overline{P'_A G'_B})}_{(V)} \qquad (9)$$

Table 1. Dimensionless Eulerian spatial correlation parameters for transport of property of concentration P in an isotropic incompressible turbulent field (*)

Correlation	Definition	
	$\underline{P}$ as vector quantity (components P_i, P_j, P_k) (momentum transfer)	P as a scalar quantity (heat, mass transfer)
First-type	$c_i^I = (\overline{p'_A v'_{iB}})/(p'' v'')$ (10)(**) (ith component of vector $\underline{c}^I$)	$c_i^I = (\overline{P'_A v'_{iB}})/(P'' v'')$ (11) (ith component of vector $\underline{c}^I$)
Second-type (double correlation)	$c_{ij}^{II} = (\overline{P'_{iA} P'_{jB}})/(P'')^2$ (12) (ijth component of tensor $\underline{\underline{c}}^{II}$)	$c^{II} = (\overline{P'_A P'_B})/(P'')^2$ (13) (scalar)
Third-type	$c_{ij,k(A,B)}^{III} = (\overline{v'_{iA} P'_{jA} P'_{kB}})/[v''(P'')^2]$ (14) (ijkth component of third-order tensor $\underline{\underline{c}}^{III}$)	$c_i^{III} = (\overline{v'_{iA} P'_A P'_B})/[v''(P'')^2]$ (15) (ith component of vector $\underline{c}^{III}$)

(*) Simplifications have been made by invoking the properties of homogeneous isotropic pulsations: $P''_{iA} = P''_{jA} = P''_{kA} = P''_A = P''_B = P''$, etc., where the double prime denotes the r.m.s. value of the corresponding fluctuating quantity.

(**) Note that in the momentum transfer case the fluctuating part of the static pressure p is used by convention .

The first, second (double) and third type dimensionless Eulerian spatial correlation coefficients c^I, c^{II}, c^{III} between fluctuations of quantities at points A and B at the same instant in time are now defined in general form as shown by equations (10) - (15) in Table 1. In terms of these correlation coefficients, equation (9) can then be written:

(i) for P as a scalar quantity:

$$\frac{\partial c^{II}}{\partial t} + (v'') \sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(c_{iB}^{III} - c_{iA}^{III}) = 2M \sum_{j=1}^{3} \frac{\partial^2 c^{II}}{\partial \delta_j^2} +$$
$$- \frac{1}{(P'')^2} \sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(\overline{F'_{jB}P'_A} - \overline{F'_{jA}P'_B}) + \frac{1}{(P'')^2}(\overline{P'_B G'_A} - \overline{P'_A G'_B}) \qquad (16)$$

(ii) for P as a vector quantity:

$$\frac{\partial c_{ij}^{II}}{\partial t} + (v'') \sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(c_{i,jk(A,B)}^{III} - c_{ij,k(A,B)}^{III}) = 2M \sum_{j=1}^{3} \frac{\partial^2 c_{ij}^{II}}{\partial \delta_j^2} +$$
$$- \frac{1}{(P'')^2} \sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}(\overline{F'_{jB}P'_{iA}} - \overline{F'_{jA}P'_{kB}}) + \frac{1}{(P'')^2}(\overline{P'_{kB} G'_A} - \overline{P'_{iA} G'_B}) \qquad (17)$$

These general equations can then be rewritten simply for the commonest cases of transport in a turbulent field, when P represents the momentum, heat, or mass of component X, per unit volume of multicomponent incompressible fluid.

Table 2. Equivalents of terms in general equation for cases of Heat, Mass and Momentum transfer in an incompressible isotropic turbulent field.

General term	Equivalent for		
	Momentum transfer	Heat transfer	Mass transfer of component X in mixture of X and Y.
P'(+) (intensive property transferred)	$P' = \rho \underline{v}'$ (momentum/unit vol.)	$P' = \rho C_p T'$ (heat content per unit volume)	$P' = \rho'_X$ (mass of component X per unit volume)
π' (molecular flux of property)	$\pi' = \underline{\underline{\tau}}'$ (momentum flux, shear stress) (*)	$\pi' = \underline{q}'$ (heat flux)(*)	$\pi' = \underline{j}'_X$ (mass flux)(*)
F' (rate of generation of property per unit surface)	$F' = p'$ (static pressure)	$F' = 0$ (**)	$F' = 0$ (***)
G' (rate of bulk generation of property per unit volume)	$G' = \underline{g}' = 0$ (constant gravity acceleration force)	$G' = 0$ (++)	$G' = -k_1^* \rho'_X$ (+++) (1st order homogeneous reaction)
M (kinematic transport property)	$M = \nu$ (kinematic viscosity)	$M = \alpha$ (thermal diffusivity)	$M = D_{XY}$ (mass diffusivity)
c^I (#) (first-type correlation parameter)	${}^M c^I_i = (\overline{\overline{p'_A v'_{iB}}})/(p'' v'') = 0$	${}^T c^I_i = (\overline{\overline{T'_A v'_{iB}}})/T'' v'' = 0$	${}^m c^I_i = (\overline{\overline{\rho'_{XA} v'_{iB}}})/\rho''_X v'' = 0$
c^{II} (double correlation parameter)	${}^M c^{II}_{ij} = (\overline{\overline{v'_{iA} v'_{jB}}})/(v'')^2$	${}^T c^{II} = (\overline{\overline{T'_A T'_B}})/(T'')^2$	${}^m c^{II} = (\overline{\overline{\rho'_{XA} \rho'_{XB}}})/(\rho''_X)^2$
c^{III} (third-type correlation parameter)	${}^M c^{III}_{ij,k(A,B)} = \dfrac{(\overline{\overline{v'_{iA} v'_{jA} v'_{kB}}})}{(v'')^3}$	${}^T c^{III}_i = \dfrac{(\overline{\overline{v'_{iA} T'_A T'_B}})}{v''(T'')^2}$	${}^m c^{III}_i = \dfrac{(\overline{\overline{v'_{iA} \rho'_{XA} \rho'_{XB}}})}{v''(\rho''_X)^2}$

(+) Constant ρ (incompressibility) is assumed throughout. The additional complexities arising when the fluid is compressible ($\rho = \bar{\bar{\rho}} + \rho'$) can be readily appreciated at this point.

(++) It is assumed that the heats of mixing and homogeneous chemical reaction can be neglected in comparison with other terms.

(+++) A first-order chemical reaction (homogeneous) of component X is assumed. Simple relationships are possible only for this case and the case of no reaction. The problem is discussed in detail by Corrsin (8).

(*) The fluxes are defined here as the quantities of momentum, heat or mass transferred per unit time per unit area normal to the transfer direction by molecular mechanisms relative to the mass-average velocity of the system.

(**) It is assumed that the viscous dissipation of flow energy to heat is zero. This is customary, but is never exactly justified.

(***) There is no mechanism by which mass of component X may be generated at a surface in a fluid phase. Generation of X at a catalyst surface, for instance (surface of a fluid phase) by heterogeneous reactions must be taken into account by boundary conditions imposed on the transfer equations.

(#) It is readily shown that all the first-type correlation parameters reduce to zero for isotropic turbulence.

The corresponding equivalents of each term in the general equations (16), (17) are given in Table 2. Substituting these equivalents, we obtain the propagation equations for c^{II} in the cases of Momentum transfer:

$$\frac{\partial}{\partial t}({}^M c^{II}_{ij}) + (v'')\sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}({}^M c^{III}_{i,jk(A,B)} - {}^M c^{III}_{ij,k(A,B)}) = \frac{2\mu}{\rho} \sum_{j=1}^{3} \frac{\partial^2}{\partial \delta_j^2}({}^M c^{II}_{ij}) \qquad (18)$$

Heat transfer:

$$\frac{\partial}{\partial t}({}^T c^{II}) + (v'')\sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}({}^T c^{III}_{iB} - {}^T c^{III}_{iA}) = 2\alpha \sum_{j=1}^{3} \frac{\partial^2}{\partial \delta_j^2}({}^T c^{II}) \qquad (19)$$

Mass transfer:

$$\frac{\partial}{\partial t}({}^m c^{II}) + (v'')\sum_{j=1}^{3} \frac{\partial}{\partial \delta_j}({}^m c^{III}_{iB} - {}^m c^{III}_{iA}) = 2D_{XY} \sum_{j=1}^{3} \frac{\partial^2}{\partial \delta_j^2}({}^m c^{II}) - 2k_1^*({}^m c^{II}) \qquad (20)$$

As can be seen, the equations describing the behavior of c^{II} also involve the next higher correlation, c^{III}, as a result of the closure problem.

. . . we show that the unified approach can be readily and conveniently applied to the study of turbulent transfer processes.

Up to this point, no use has been made of the assumed isotropic nature of the turbulent field except to somewhat simplify the definitions made in Table 1. The isotropic properties of the turbulence can now be invoked to represent c^{II} and c^{III} in terms of scalar functions f, h, q, w of the time t and the distance $\underline{r}$ between measurement points which have the appropriate transformation properties. Using the usual manipulations *(2, 3, 4, 5), which need not be repeated here, we finally obtain the von Kármán - Howarth equation (6) for the dynamic behavior of the Eulerian double velocity correlation:

$$\frac{\partial}{\partial t}[(v'')^2 f] = 2\nu (v'')^2 \left(\frac{\partial}{\partial r} + \frac{4}{r}\right)\left(\frac{\partial f}{\partial r} - \frac{v''h}{\nu}\right) \qquad (21)$$

the Corrsin equation (7) for the dynamic behavior of the Eulerian double temperature correlation:

$$\frac{\partial}{\partial t}[(T'')^2 w_T] = 2\alpha (T'')^2 \left[\frac{\partial^2 w_T}{\partial r^2} + \frac{2}{r}\frac{\partial w_T}{\partial r}\right] - 2(T'')^2 v''\left(\frac{\partial q_T}{\partial r} + \frac{2q_T}{r}\right) \qquad (22)$$

and the Corrsin equation (8) for the dynamic behavior of the double concentration correlation (for the case involving a first-order chemical reaction):

$$\frac{\partial}{\partial t}[(\rho''_X)^2 w_m] = 2D_{XY}(\rho''_X)^2 \left[\frac{\partial^2 w_m}{\partial r^2} + \frac{2}{r}\frac{\partial w_m}{\partial r}\right] + 2(\rho''_X)^2 v''\left(\frac{\partial q_m}{\partial r} + \frac{2q_m}{r}\right) - 2k_1^*(\rho''_X)^2 w_m \qquad (23)$$

With suitable assumptions as to the behavior of the third-order terms (h, q), these equations have been solved for particular cases to obtain the decay of the respective double correlations under isotropic turbulent conditions (5). These results are of some practical interest since the double autocorrelation terms (for the special case when $\underline{r} = 0$ are closely related at a given level of turbulence to the Reynolds stresses, and analogous heat and mass transfer terms, which appear in the phenomenological studies of turbulence.

To sum up, we feel that the unified approach used here underlines the similarity between the turbulent transport of heat, mass and momentum even in so esoteric an application as the one considered here. The main sources of difference also become clear, such as the fact that in momentum transfer the quantity transferred is a vector quantity, while in heat and mass transfer, the

* An additional operation of contraction must be carried out in the case of equation (18), where P is a vector quantity.

Nomenclature.

C^{I}, C^{II}, C^{III}	general first-, second-, and third-type dimensionless Eulerian spatial correlation parameters, defined in Table 1.
${}^{M}C$, ${}^{m}C$, ${}^{T}C$	special cases of the corresponding C^{I}, C^{II}, C^{III} parameters for momentum, mass and heat transfer.
C_p	isobaric heat capacity (assumed constant throughout).
D_{XY}	Molecular mass diffusivity of X in binary mixture of X and Y (assumed constant throughout).
$f = f(\underline{r}, t)$	scalar function replacing ${}^{M}\underline{\underline{C}}^{II}$ in isotropic turbulence.
$F = \bar{\bar{F}} + F'$	rate of generation of general property per unit surface area in fluid.
$\underline{g}$	gravity acceleration (assumed to be only body force).
$G = \bar{\bar{G}} + G'$	rate of bulk generation of general property per unit volume of fluid.
$h = h(\underline{r}, t)$	scalar function replacing ${}^{M}\underline{\underline{\underline{C}}}^{III}$ in isotropic turbulence.
$\underline{j}_X = \underline{\bar{\bar{j}}}_X + \underline{j}'_X$	molecular mass flux of component X relative to mass-average velocity.
k_1^*	first-order homogeneous chemical reaction rate constant (assumed to be a true constant).
M	kinematic molecular transport property for general property of system.
$p = \bar{\bar{p}} + p'$	static pressure.
$P = \bar{\bar{P}} + P'$	quantity of general property per unit volume of system.
$\underline{q} = \underline{\bar{\bar{q}}} + \underline{q}'$	conduction heat flux, relative to mass-average velocity.
$q_m = q_m(\underline{r}, t)$, $q_T = q_T(\underline{r}, t)$	scalar functions replacing ${}^{m}C^{II}$ and ${}^{T}C^{II}$, respectively, in isotropic turbulence.
r	scalar radial distance in isotropic turbulence.
$\underline{r} = \delta_i + \delta_j + \delta_k$	vector distance between points at which correlation is determined.
t	time.
T	temperature.
$\underline{v}$, v_j	velocity vector and its components
$w_m = w_m(\underline{r}, t)$, $w_T = w_T(\underline{r}, t)$	scalar functions replacing ${}^{m}\underline{C}^{III}$ and ${}^{T}\underline{C}^{III}$, respectively, in isotropic turbulence.
$\underline{x}$, x_j	Cartesian coordinates.
α	thermal diffusivity (assumed constant throughout).
$\delta_i = x_{iA} - x_{iB}$	x_i-component of distance between points A, B at which correlation is determined.
μ	dynamic viscosity.
ν	kinematic viscosity (assumed constant throughout).
$\pi = \bar{\bar{\pi}} + \pi'$	molecular flux of general intensive property.
ρ	density of fluid (assumed constant throughout).
ρ_X	mass concentration of component X.
$\underline{\underline{\tau}} = \underline{\underline{\bar{\bar{\tau}}}} + \underline{\underline{\tau}}'$	molecular momentum flux (or shear stress) relative to mass-average velocity of fluid.

Subscripts.

A, B	quantities measured at points A, B, distant $\underline{r}$ apart, at same instant in time.
i, j, k	in directions of x_i, x_j, x_k axes.
X, Y	components X, Y of binary mixture.
Q, $\underline{Q}$, $\underline{\underline{Q}}$, $\underline{\underline{\underline{Q}}}$	scalar, vector, tensor (2nd-order tensor), and third-order tensor quantities Q.

Superscripts.

Q'	fluctuating part of Q.
Q''	r.m.s. value of fluctuating part of Q
$\bar{\bar{Q}}$	time-averaged part of Q.
M, m, T	momentum, mass, heat transfer quantity, respectively.

property is a scalar, leading to slightly different forms of the main equation. The appearance of chemical reaction term in the mass transfer case is also of interest. It can also be seen that the generalized equation will make it relatively simple to obtain equations for the dynamic behavior under the conditions considered here of other turbulently pulsating conserved quantities, such as electric charge per unit volume, which may become important in the study of turbulent plasmas. □

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BOOK REVIEW (from p. 127)

summary of the principal characteristics of macromolecular systems, followed by the three major sections of the book, dealing with polymer synthesis, solid state properties, and polymer rheology. The author has managed to organize and unify the main features of polymer science quite satisfactorily. The transition from subject to subject is smooth, and the informal style and sense of awareness of the students' background should make the book eminently readable and useful as an introductory text. The introductory section, the section on polymer physics, large portions of the section on polymer systhesis, and the chapter on linear viscoelasticity of polymer solids are especially well done.

The coverage is by no means comprehensive, however. It omits such important subjects as polymer solutions, molecular characterization, the chemistry and statistics of crosslinking, and effects of molecular structure on flow properties. Indeed, the weakest part of the book is its treatment of rheology and polymer processing. Also, the discussions of the glass transition, ionic polymerizations of all kinds, crystallization kinetics, and the quantitative techniques for characterizing crystalline polymers are rather cursory. Some telescoping is necessary for the reasons discussed

(Continued on page 140.)

ChE views and opinions

IMPROVING COLLEGE TEACHING In Chemical Engineering

JAMES M. HENRY*
Yale University
New Haven, Conn. 06520

This paper touches upon some aspects of a program which would better prepare prospective college teachers for their careers and at the same time be of benefit to small and/or young Schools of Engineering.

THE NEEDS OF PROSPECTIVE COLLEGE TEACHERS

Many Chemical Engineering Departments have long realized that some experience in teaching assistance by graduate students is a valuable part of the educational program. As such, most graduate students during their tenure serve at least one semester as Teaching Assistants. This experience, however, seems to be insufficient for the student who does plan to enter a career in college teaching.

A prospective college teacher needs to have experience in all espects of teaching in order to be prepared for his profession. Among those aspects are preparing lectures, delivering lectures, assigning homework, preparing examinations, counselling students, preparing laboratory sessions, directing laboratory work, and grading student work. It is only the last two that are ordinarily encountered by the Teaching Assistant.

THE NEEDS OF DEVELOPING COLLEGES

For the purpose of discussion, "developing college" may be considered one in which the Chemical Engineering program is below accreditation level and has four or fewer faculty members (at publication time there are some 10 or 12 institutions meeting this description). The pros and cons of actual accreditation are not considered here, but it is assumed that the specifications for accreditation are sound educational requirements. Selected qualifications for an accredited program as set forth by the American Institute of Chemical Engineers[2] are (1) instructional methods should provide close faculty-student contact, (2) teaching loads must not be excessive, and (3) staff activity in research is desirable.

THE NEEDS OF ACADEMICALLY DISADVANTAGED STUDENTS

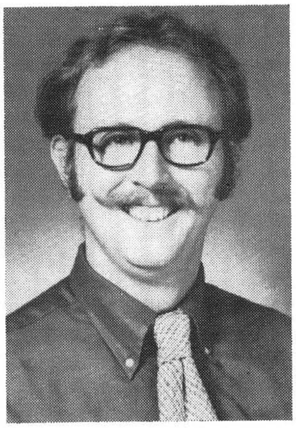
There are many students now in college and soon heading for college whose academic background is not of top quality, both in terms of subject matter coverage and motivating influences. Students of this type are in need of some motivation to stimulate them to more fully realize their abilities and opportunities. Such students in engineering need a modern presentation of fundamental engineering and an introduction to advanced engineering developments. Many students meeting this description are now in or plan to attend the previously mentioned developing colleges (the reasons for this may be family or ethnic tradition or admission policies or other, but will not be discussed here).

PROPOSAL

Generalities. It is proposed that a partial fulfillment of all the needs as mentioned above can be realized by a program under which graduate students are placed as short-term faculty members in some developing colleges. This program should be optional and voluntary, simply an opportunity open to any interested graduate student. The experience gained in this teaching situation can materially benefit the graduate student in his teaching career and also be an aid in his own education as he more clearly organizes the fundamentals of engineering.

The college can gain needed manpower to help in the instruction of laboratory and computational classes (both of which can be most effectively conducted by recently educated engineering graduates) and in reduction of teaching load. Then, too, if the teaching assignment were little enough to allow the graduate student to continue his thesis research, this example could infuse

* Present address: U.S. Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213



Jim Henry received his chemical engineering degrees at Rice and Princeton Universities. He was a Woodrow Wilson Teaching Intern at Prairie View A&M College for two years in the Electrical Engineering Department before finishing his graduate work. Dr. Henry has been a Lecturer at Yale University in Engineering and Applied Science and is presently at the Pittsburgh Energy Research Center of the U.S. Bureau of Mines.

within the other college personnel an ambition to further their professional activity. The youthful approach to instruction and close faculty-student contact which the graduate student should exhibit could contribute added freshness to the college's program, faculty, and students.

The example set by this graduate student in achievement and his personal counselling would be of tremendous benefit to the student body. The interim teacher could advise on higher career objectives to the students, possibly encouraging some to continue their education in graduate school.

Technicalities. This proposed program could be developed on a continuing basis among several colleges or as **ad hoc** relation for a particular college or student. It is thought that a convenient time in the graduate student's tenure to participate in such a program would be the semester following the qualifying for the Ph.D. candidacy or a semester during which his advisor is on leave (or some combination of the two). The length of the teaching assignment should be determined as a balance between short term (one semester) which would be least interfering to the graduate student's progress, and long term (three or more semesters) which would be of greater value to the school and its students. One year, or two semesters, seems to be a "natural" suggestion because of various mundane outside constraints (e.g., "standard" contracts, registration in graduate school, draft boards, housing arrangements).

The continuing of research by the graduate student would probably be restricted to theoretical or computational aspects and/or experimental design in connection with his thesis topic. Even the performance of some preliminary experiments may be feasible, not ruling out some cooperation from the school's Chemistry Department. It is not uncommon to find good, well-equipped Chemistry Departments in small colleges, eager to utilize research man-power.

Salary arrangements for the teaching student should be solely between the school and the student. This period at "regular pay" will surely be welcomed by the graduate student and will release his assistanceship from the graduate department for other use. Whether either of these latter benefits is real or not may be debated.

The single evident hindrance to implementation of this proposition is the matter of relocation. With some coincidental exceptions this teaching appointment would require a change of residence by the graduate student. A working spouse or school children would make this particularly troublesome.

Alternatives. With respect to the needs of the developing colleges and their students, several alternative teacher-placement services are in operation. These range from the ASEE arrangements for retired faculty, through various programs for visiting professor appointments, to the Woodrow Wilson Teaching Intern program for graduate students and new Ph.D.'s.

The needs of most Chemical Engineering graduate students, as discussed above are not fully met by existing arrangements. Satisfying these needs in post-doctoral appointments is entirely reasonable, and is not to be discredited; however, post-doctoral appointments usually emphasize the research rather than the teaching activity of universities. The placement of graduate student teachers as proposed here is intended to supplement and quite possibly even reinforce existing internship programs at the post-doctoral level. In addition, most likely the graduate student returning from this proposed teaching assignment can stir interest for college teaching in Chemical Engineering among other graduate students.

CONCLUSIONS

A program for college teaching practice as proposed here will be of benefit to the growth in

Chemical Engineering education. The experience gained by the practice teacher is not incompatible with developing professional engineering experience. By considering a broad definition of engineering, the profession of developing available resources to be useful to men,[3] the services rendered in assisting developing colleges and training under-achieving students are definitely legitimate egineering activities. In addition, the experienced teachers that the program can provide will be an asset in whatever positions they may assume after graduate school. As beginning faculty in universities, the trial of initial teaching duties will not be unduly burdensome at a time when some new research interests are being explored.

The small Chemical Engineering Departments that may participate in this program will be benefited in the short term simply with respect to more faculty. In addition, possibly some of the "practice teachers" will be induced to return to the same college and aid its development. The benefits to the students of a practicing teacher may be more psychological than educational. The new teacher will make mistakes in academic matters at the expense of the students, but as a symbol of youth and scholarly excitement, the new teacher can favorably motivate many students to higher goals. □

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ChE laboratory

Chemical Reactor Laboratory

BIOLOGICAL REACTIONS: KINETICS OF YEAST GROWTH

JAMES B. ANDERSON*
Princeton University
Princeton, N. J. 08540

This is the third in a series[1] of articles describing an undergraduate chemical reactor laboratory designed for seniors in the Department of Chemical Engineering at Princeton. Professor Richard H. Wilhelm provided the inspiration for the successful development of the laboratory. The basic objectives are outlined in the first article of the series.

The experiment described here provides students with an introduction to biological processes and techniques by demonstrating the transfer of reaction engineering knowledge learned in non-biological systems to the kinetics of yeast growth. The increasing understanding of biological systems and recognition of their importance in chemical processing indicate the value of familiarity with biological processes. The growth of yeast under aerobic conditions is a relatively simple experiment for which the kinetics of growth may be compared with theoretical behavior.

The experiment is patterned after the commercial process for growing yeast in which an initial charge of yeast in a nutrient solution is allowed to multiply and grow. An excess of all nutrients except sugar is provided. Under these conditions the rate of growth is a function of the yeast present and the amount of sugar present. After an induction period the yeast growth rate is rapid. As the sugar present is depleted the growth rate decreases and falls to zero at the end of the experiment. The yeast cell volume and sugar concentrations are measured over the period of the experiment and the results compared with predictions.

The growth of yeast is carried out over a ten-hour period. An additional three hours is required for analysis of samples for sugar concentration. Yeast cell volume is determined by centrifugation while sugar concentration is de-

*Present Address: Department of Engineering and Applied Science, Yale University, New Haven, Conn. 06520.

The experiment is patterned after the commercial process for growing yeast . . . and it demonstrates the transfer of reaction engineering knowledge learned in non-biological systems to the kinetics of yeast growth.

termined by a modification of a colorimetric method commonly used in analysis for sugar in blood.

THEORETICAL BACKGROUND

Several general reviews of the application of engineering techniques to biological processes are available[2]. The kinetics of reactions in micro-organisms have been treated in books by Hinshelwood[3] and Bray and White[4]. Humphrey and Diendoerfer[5] have furnished an excellent review of fermentation.

Yeasts are formally classified as plants, but like animal organisms they utilize the oxidation of carbon in the form of sugar to carbon dioxide as a source of energy. Under anaerobic conditions yeast is able to use the oxygen in the sugar molecule, giving off alcohol and carbon dioxide as waste products, but growth is relatively slow. Under aerobic conditions yeast growth is greatly enhanced and the waste products are primarily acids and aldehydes together with carbon dioxide. In addition to sugar and oxygen yeast requires a nitrogen source in the form of ammonia or amino acids and several minerals and vitamins in order to grow and multiply.

The kinetics of yeast growth follow a pattern similar to that of adsorption and catalysis in that a large number of parameters, each with saturation effects, is involved. After an initiation period in which the yeast becomes accustomed to a new environment, the growth rate is first order in yeast concentration and also depends on the concentrations of sugar, oxygen, available nitrogen, minerals, vitamins, hydrogen ion concentration and temperature. Hinshelwood[3] formulated the rate equation as a product of terms for each of the vital substances,

$$\frac{dY}{dt} = kY\left(\frac{b_sC_s}{1+b_sC_s}\right)\left(\frac{b_oC_o}{1+b_oC_o}\right)\left(\frac{b_nC_n}{1+b_nC_n}\right)\cdots\left(\frac{b_xC_x}{1+b_xC_x}\right) \tag{1}$$

where Y is the yeast cell volume per unit volume of solution, k is a rate constant, C_S is the sugar concentration, b_S is a constant for sugar, and so forth for oxygen (o), nitrogen (n) and others. It is assumed that other variables such as temperature and pH are constant. For an excess of any of the nutrients the product bC becomes large compared to unity and the term in brackets approaches unity.

In the experiment considered all nutrient substances except sugar are supplied in large excess so that the rate expression becomes

$$\frac{dY}{dt} = kY\,\frac{b_sC_s}{1+b_sC_s} \tag{2}$$

Since yeast growth occurs both by the growth of individual cells and by cell division with further growth and division of new cells, a rate equation for the number of cells per unit volume may differ slightly from that for the volume of yeast per unit volume.

A material balance for the sugar may be used to relate sugar and yeast concentrations:

$$R(Y - Y^o) = C_s^{\,o} - C_s \tag{3}$$

where 1/R is the yeast cell volume which results from the utilization of a unit amount of sugar and the superscript o indicates an initial value. Combining with Eqn. (2) to eliminate C_S yields

$$\frac{dY}{dt} = kY\left[\frac{b_s(C_s^{\,o} - R(Y - Y^o))}{1 + b_s(C_s^{\,o} - R(Y - Y^o))}\right] \tag{4}$$

which may be integrated for the initial condition, $Y = Y^o$ at $t = 0$, to give

$$Y = Y^o e^{kt}\left[\frac{Y^o}{Y}\left(1 - \frac{R}{C_s^{\,o}}(Y - Y_o)\right)\right]^{\frac{1}{b_s(C_s^{\,o} + RY^o)}} \tag{5}$$

The growth curve of Eqn. (5) will not include the induction period and transition at the start of growth nor the loss of cell volume after the sugar has been consumed.

APPARATUS

The reaction is carried out in a 30-liter fermentor equipped with an agitator, water coils, air sparger and sampling ports. Temperature is controlled by circulating water from an auxiliary constant-temperature bath through the fermentor coils. A photograph of the fermentor is shown in Figure 1.

Air supplied to the sparger located below the agitation blades is passed through a 1-inch diameter, 0.8 micron pore-size Millipore filter to remove contaminants. A 1.2-SCFM rotameter is included in the air feed line.

Samples of the medium are placed in 12-ml, tapered, graduated centrifuge tubes which are subsequently placed in a high speed centrifuge. A lower cost centrifuge would probably be adequate.

If samples to be analyzed for sugar are to be stored, a freezer is required. The colorimeter

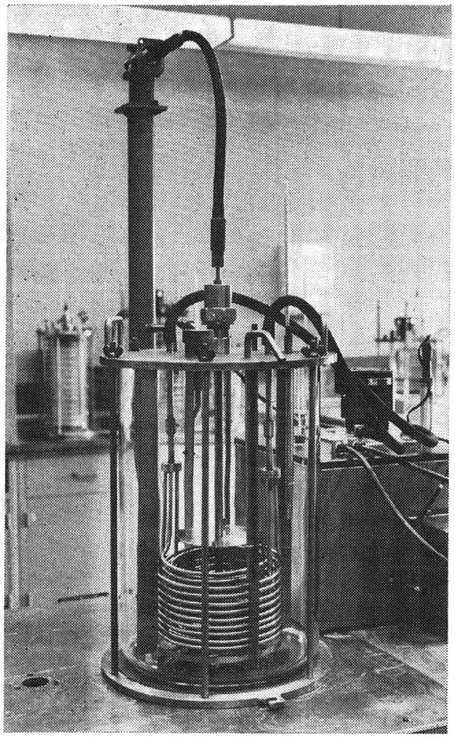

Figure 1. Fifteen-liter fermentor for yeast growth.

analysis is carried out with a Beckmann Model DU Spectrophotometer. In addition an assortment of specialized laboratory glassware is required.

PROCEDURE

The growth medium used is 500 g of dextrose (cane sugar) and 200 g of nitrogen base (Bacto, dehydrated) containing nitrogen and necessary trace elements and vitamins all dissolved in 15 liters of water. Since yeast is fairly resistant to disease, complete sterilization is unnecessary but the sugar and nitrogen base are heated to 90°C for 5 minutes prior to use. Distilled water is used. The solution is placed in the fermentor and heated to 29°C. The air flow is started and 20 g of Fleischmann's dry yeast is added.

Samples are taken with a pipette at intervals of one-half to one hour for approximately ten hours or until yeast growth has ceased. Since the yeast tends to concentrate in the foam produced by sparging, care must be taken to obtain representative samples.

To eliminate its effect on growth the pH of the medium is kept constant in the range of 5.0 to 5.5 units. The pH is tested at 15-minute inervals with pH paper and excess acidity is neutralized with concentrated ammonium hydroxide.

Samples are placed in centrifuge tubes and centrifuged to produce a compact yeast mass at the bottom of the tubes. Cell volume is recorded as the volume of the yeast mass produced. Since the yeast may continue to produce carbon dioxide which may swell the volume of the yeast mass, readings of cell volume must be taken immediately after centrifugation.

The supernatant liquid is collected for subsequent sugar analysis. Some yeast remains in this liquid and must be prevented from decreasing the sugar content. A drop of phenol is added and the solution is frozen.

The sugar determination is made by the colorimetric method of Nelson[6-10] which is not affected by the presence of other compounds. Samples are thawed and diluted to give sugar concentrations of about 0.2 mg per ml. Duplicates of each unknown are desirable. Both samples and standard solutions are treated by boiling with a copper reagent and adding an arsenomolybdate color reagent. The absorbances of the resulting solutions are measured at 500 mu with a Beckmann Model DU Spectrophotometer using standard techniques.

Results are compared with Eqns. (2) and (5) with allowance for an initiation period of one to two hours. The constants $C_S°$ and $Y°$ are known from direct measurement. The value of k is determined from the rate during the initial growth period when sugar is present in excess and Eqn. (2) becomes

$$\frac{d \ln Y}{dt} = k \qquad (6)$$

When sugar concentration affects the rate the term $\left[\frac{b_s C_s}{1 + b_s C_s}\right]$ becomes important and b_S may be evaluated from the slope of a plot of $\left(k \frac{d \ln Y}{dt}\right)^{-1}$ vs. C_s^{-1} vs. C_S^{-1}. The value of R is determined from yeast and sugar balances. Once the constants are known the integrated rate equations may be tested.

STUDENT PERFORMANCE

Students are enthusiastic about this experiment and attack it as an adventure in a new area. The yeast growth and measurements of cell volume are carried out without difficulty. Left on their own the students usually fail to obtain consistent results for sugar concentration. Close supervision and detailed recipes are required for successful analyses.

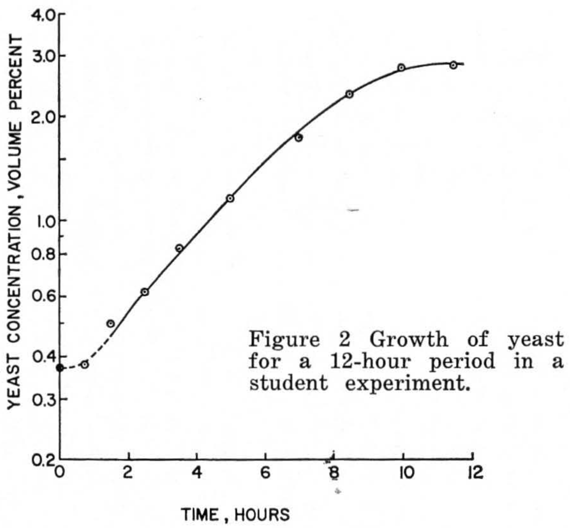

Figure 2 Growth of yeast for a 12-hour period in a student experiment.

Typical results of a student experiment are shown in Figures 2, 3 and 4 in which cell volume and sugar concentration are plotted *vs.* time and the agreement with Eqn. (5) is indicated.

DEVELOPMENT OF THE EXPERIMENT

Yeast was chosen for this experiment because of its rapid growth rate, its insensitivity to experimental conditions and its resistance to disease. A number of trials were made before suitable temperature and concentration variables were determined. Several batches of yeast were killed (obvious from the smell) for unknown reasons in the development runs.

Attempts to measure yeast concentration by counting cells in a small volume under a micro-

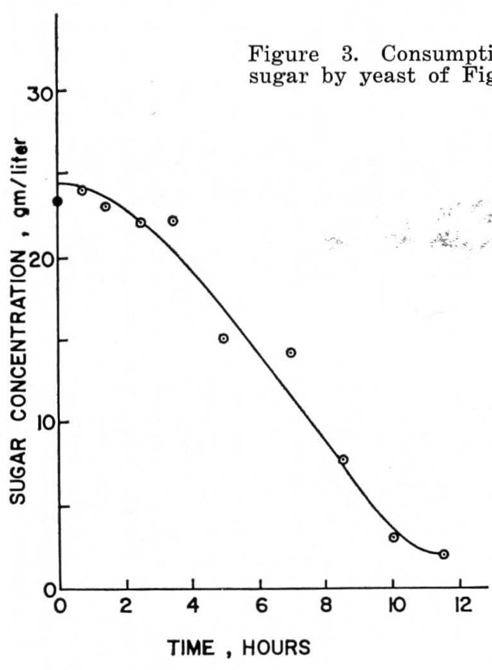

Figure 3. Consumption of sugar by yeast of Figure 2.

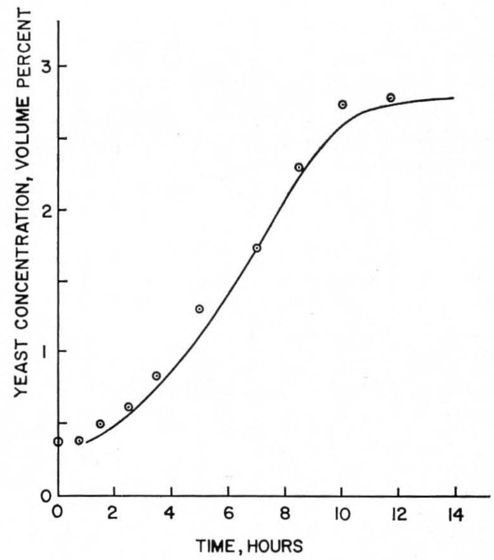

Figure 4. Comparison of theoretical growth curve with data of student experiment. Experimental points are those of Figure 2. The solid line is the theoretical behavior as calculated from Eqn. (5) with $Y^\circ = 0.0037$, $C_S{}^\circ = 22.5$ gm/liter, $R = 935$ gm/liter, $b_S = 0.105$ liter/gm, $k = 0.4$ hr^{-1}. The curve is displaced one hour to allow for the induction period.

scope were unsuccessful. The combined problems of representative sampling and the time required for counting eliminated use of this method of analysis. Turbidity measurements were attempted briefly but eliminated because differences in sample transmittance were small.

Foam formed in the latter stages of growth creates problems in taking representative samples. An anti-foam agent added at the end of a run eliminated the foam within seconds. The effect on yeast growth has not been tested but such agents are used routinely in biological laboratories. □

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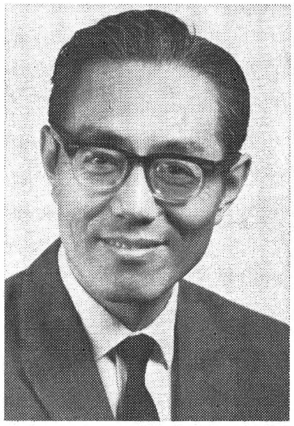
Deriving Three Thermodynamic Equations In Vapor- Liquid Equilibrium Studies

LUH C. TAO
University of Nebraska
Lincoln, Nebraska 68508



Luh C. Tao is a Howard S. Wilson Professor of Chemical Engineering at the University of Nebraska. He received his PhD from the University of Wisconsin in 1952. Since 1959, he has been at the University of Nebraska. Before that, he was with Titanium Metals Corporation of America in Henderson, Nevada. His research interests are in thermodynamics, transport phenomena and their applications to food systems.

One of the interesting and difficult aspects of teaching thermodynamics is to find the simplest way of presenting the rigorous derivations of equations especially for multicomponent systems. This note shows such a pathway of deriving three equations in the area of phase equilibrium. They are simpler than those in available textbooks. This results in time-saving in presentation and facilitates learning. It was found very useful for the instruction purposes.

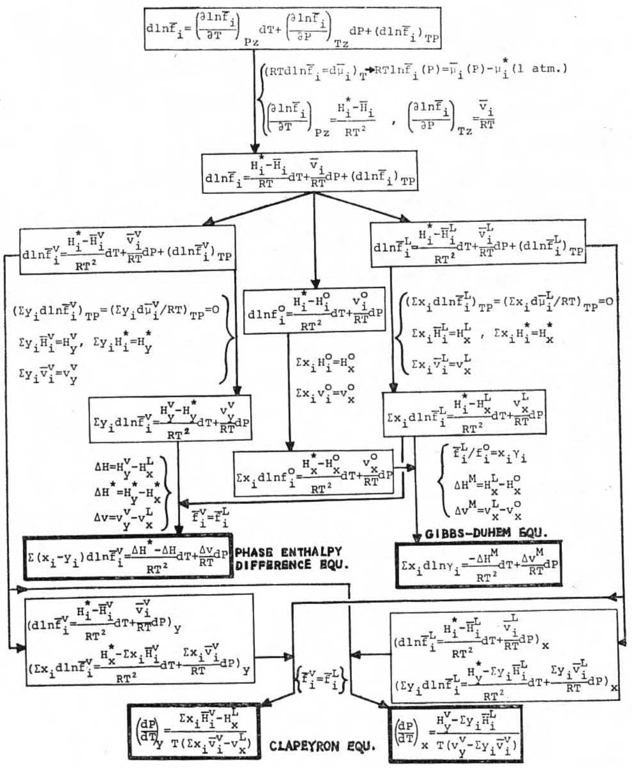
The derivation graph uses all conventional notations such as f for fugacity. Superscripts V and L indicate vapor and liquid phase, a bar — implying a mixture and for most cases also partial molal quantity, * for ideal gas and o for standard state. Subscripts x,y,z, indicate composition of mixtures and i,1,2,n, are component identities.

The first equation on the graph refers to the total variation of $\ln \bar{f}_i$ as the sum of three contributors on the right-side. They refer respectively to those due to changes of temperature, pressure and composition vector z, i.e. $(z_1, z_2, \ldots, z_n)$. It is basically the chain rule of differentiation with the use of a restrictive differential $(d\ln \bar{f}_i)_{PT}$ to represent a group of partial composition derivatives.

Following this pathway, students are made aware of all restrictions carried along. For example, the Gibbs-Duhem equation does not include the phase equilibrium criteria while the other two equations do. Therefore, to use this equation for vapor-liquid equilibrium criterion

$$\bar{f}_i^L = \bar{f}_i^V \quad \text{into} \quad \gamma_i = \bar{f}_i^L / x_i f_i^o$$

These equations are available in literature. Reference 5 shows the unrestricted multicomponent Gibbs-Duhem equation and the Enthalpy-difference equation for binary systems. Articles 3 and 4 have Enthalpy-difference equation and



Derivation Graph

Clapeyron equation for multicomponent systems. Classical and lengthy derivations of Clapeyron equation for a binary system in reference 1. This type of derivation was recently extended to a multicomponent system (ref. 2).

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BOOK REVIEW (from p. 131)

earlier, and some of the choices come down to questions of personal taste. However, it seems to me that the author missed at least one good opportunity to reinforce his earlier discussions of polymer synthesis by failing to point out some of the well established connections between flow properties and molecular structure.

In summary, the book gives a good general survey of polymer science. The omissions can be handled by supplementary lectures and outside reading. It should make a very suitable textbook for introductory courses.

William W. Graessley
Northwestern University

MISCHKE (from p. 117)

sentation of salary statistics or results of surveys which conclude that chemical engineers have happier marriages than other professions.

Emphasis of Presentation. One last point to remember is that our main function is one of guidance rather than that of strong persuasion. Our job is not to get as many people enrolled in chemical engineering as possible, but to attract those to whom chemical engineering will be inherently satisfying. Therefore, we should emphasize the choice of a career over the choice of a discipline. The flexibility and breadth of application and use of chemical engineers in a wide variety of industries—not just the chemical process industries—should be stressed, as well as how other branches of engineering can be served by chemical engineers.

Sources of Information. Some of the most meaningful data that we can present about chemical engineering is our own testimony of what we know about chemical engineering and what chemical engineering means to us. In doing this we should remember that such feelings probably will not be motivating to the audience until the basic needs have been shown to be satisfied. The AIChE publishes an excellent career guidance booklet[4] which contains information on programs for primary schools, secondary schools, junior colleges, and universities. The booklet also contains current statistical data on job opportunities, salary levels, etc., which are needed to answer questions. Incidently, a study of the list of typical questions included in the publication gives insight into the concerns and feelings of students.

SUMMARY

The problem of declining enrollments in chemical engineering is symptomatic of poor effectiveness in the career guidance work now being carried on by chemical engineers.

A number of factors operate during career guidance presentations. If these factors are considered, a presentation's effectiveness can be enhanced. If they are neglected during the design of the presentation, its effectiveness can be severely reduced. These factors include:

- The psychological needs of the audience are very different from those of the speaker.
- Motivational incentives are different for various members of a given group.
- The needs of security and belonging take precedence over the need for success.

Improved presentations may be obtained if:

- Presentations are designed as carefully as the other things which engineers design.
- Current knowledge of motivational systems and student needs is used in the design.
- The hierarchical structure of need fulfillment is recognized and made a part of the design.
- The presentation is made relevant to the current needs of the audience. □

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KUBE (from p. 113)

vening years and presently has the relation within the Institute as shown in Figure 2. The Career Guidance Committee is directly responsible to

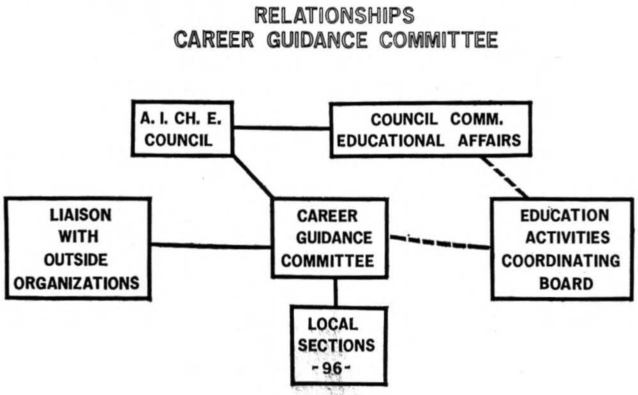


Figure 2.

the Council. Activities with the Institute are coordinated with the education activities coordinating the board which consists of the chairman of the Career Guidance, Education and Accreditation, Professional Development, Student Chapters, Continuing Education, and Chemical Engineering Education Project Committees. The Committee has attempted liaison with outside guidance organizations, quite frequently with only mediocre success. Typical organizations are Engineers Council for Professional Development, American Chemical Society, Manufacturing Chemists Association, National Science Teachers Association, Engineers Joint Council, American Personnel Guidance Association. Perhaps the two most successful arrangements have been with the Junior Engineers Technical Society (JETS) and ECPD. Arrangements in a limited area are under discussion with ACS and MCA.

Primarily the National Career Guidance Committee works with the Career Guidance Chairman of the local sections of the Institute. Each section is supposed to appoint a career guidance chairman who has a goal, the education of students, counselors, teachers and parents in what comprises chemical engineering as a profession, so that the student can make an informed decision in choosing his life's working. The philosophy is supposed to be one of information not recruitment. I presume I set the activities of the Committee back by many years by constantly referring to the activities as proselytizing.

The National Committee has a responsibility of providing the Local Section Committees with the necessary information and tools to carry out the basic guidance work. The responsibilities of the Local Section Committee is to make the direct contacts with students, teachers, counselors, and others.

All of this works fine on paper but the problem is that all of these positions are nonpaying and are in addition to the regular duties of the people involved. Consequently, only those who are extremely dedicated do any work in this field.

A disadvantage of working only through Local Sections is that the sections are usually in areas of high population and even under the best of circumstances, do not get coverage of schools outside their immediate area. Again, any contribution is made through the personal efforts and dedicated activities of those in the Local Sections.

To provide contact, and to disseminate information to the Local Sections, a newsletter containing developments and suggestions is distributed three times a year. To provide some continuity, a portfolio consisting of visual aids, career guidance brochures and general instructions are provided to each Local Section Chairman. It is a continuing activity to update and improve this portfolio. Use of symposia and training sessions at National Meetings are useful. Data, statistics, mailing lists, bibliographies and other working documents pertinent to science and engineering professions are distributed as available.

Many suggestions have been made concerning work in areas effecting activities of students, teachers, counselors and parents. With the student, some effective activities are lectures at career days, being judges at science fairs, organize planned trips for students, give them summer jobs in plants, provide pertinent literature, assist with JETS chapters and science and chemistry clubs, and even provide scholarships. The teachers and counselors can generally be educated in the facets of profession and find out what chemical engineering is if taken on plant trips, or provided summer jobs in significant positions. An effective method has been to invite science teachers and/or counselors to Local Section at dinner meetings. One year we had the slogan, "Take a Science Teacher to Lunch."

It is apparently more effective to establish rapport with the science teacher rather than the counselor. If one can get a high school science teacher enthusiastic about a summer project, this carries over very well into the classroom and is highly effective. With parents it is suggested that a Local Section representative accept speaking engagements with organizations such as parent-teacher associations.

Essentially all the National Career Guidance Committee can do is suggest possible methods of contact and furnish some basic material to the Local Sections. Special circumstances for each Local Section makes it impossible to be quite specific. What may work in a New York section would not be applicable to an Iowa or the Minneapolis-St. Paul section.

BROCHURE

Many times it is nice to have something to send or to hand out specifically directed towards chemical engineering. The National Career Guidance Committee planned a two-step procedure. For the first step they developed an ad printed in a throw-away type brochure entitled, "Chemical Engineering and You." This brochure was to serve as initial contact with a second more extensive and permanent type brochure to be available for more interested students, counselors or high school science teachers. Meanwhile the JETS organization devoted one of their Journal issues to chemical engineering and Volume 16, No. 6, Feb. 1969, was published. There has been at least two reprintings of the issue and over 15,000 reprints distributed. This great demand for reprints indicates the necessity of completing an attractive permanent type brochure.

FILM

Most of you are familiar with the film put out by the Institute entitled, "The Chemical Engineer."

It has been edited to remove dated material and the revised film is available from the National Office.

DOCTOR HECKMAN'S PROGRAM

Dr. Heckman, Chairman of ChE in South Dakota School of Mines, initiated a program of direct contact with high school students. The basis of this was selection of students who were apparently qualified to become chemical engineers as evidenced by their ACT or other college test scores. Contact was made by personal letters explaining what chemical engineering is and inviting further inquiries. Under the circumstances at South Dakota this worked amazingly well. Dr. Heckman has been successful in the last few years in vastly increasing enrollment in ChE in his department. National Career Guidance Committee wanted to find out if this method would work at other institutions, and at present have three additional schools working on a modification. Circumstances at the various schools differ but basically the programs are the same as Dr. Heckman's. Each of the three additional schools have reported significant increases in enrollment, usually in the face of a declining overall enrollment in their engineering college. Apparently the methods work but there are a few pitfalls. By "grape vine" I understand that Dr. Heckman's program is in some difficulty because student organizations have claimed that he has violated some "freedom" by making a selection based on test scores (ability) and the selection procedures are no longer available to him.

PROGRAM FOR DISADVANTAGED YOUTH

Previously I have mentioned that minority groups could be a particularly fruitful area for recruitment for engineers. Children in minority groups are often disadvantaged in regards to their basic education but not ability. Very few finish high school with a background to take engineering in college. Again the problem is motivation and the National Career Guidance Committee has a permanent subcommittee to work on this specific problem. Some 15 Local Sections have special programs in this area. The main thrust of the programs are towards motivation of the junior high school students so that they would take the required high school courses and be so motivated that they would do well. The program has not been underway long enough to have any measure of success, but potentially it could be very successful.

I have attempted to ask some basic questions in regards to the motivation of students into engineering and specifically chemical engineering. No one has all of the answers. What works under one set of circumstances may not be applicable in a different situation. The secret is that of a dedicated person working as best he knows how to contact and motivate bright young minds into the engineering fields. There is no substitute for the personal touch and this is best achieved through much practice and above all, dedication and interest in what is best for the student. □

Organic and Physical CHEMISTRY COURSES In 89 ChE Curricula

JAMES T. COBB, JR.
University of Pittsburgh
Pittsburgh, Penn. 15213

James T. Cobb, Jr. received the S.B. degree from M.I.T. and the MS and PhD degrees from Purdue University. Following two years in the weather modification group at the Naval Weapons Center in China Lake, California, he was an engineer for three years at the Esso Research Laboratories in Baton Rouge, Louisiana. His current interest is in reaction engineering. He is active in AIChE at both the local and national level.

The School of Engineering at the University of Pittsburgh has a one-and-a-half year common curriculum for its freshmen and first-term sophomores. As a result, the Chemical Engineering curriculum requires Chemical Engineering majors to take seven credits of organic chemistry and eight credits of physical chemistry in their junior year.

The faculty of the Chemical Engineering Department is concerned that this requirement places a severe burden on our juniors. As a tool to guide the faculty in studying this problem, a review has been made of the organic and physical chemistry requirements of 89 chemical engineerin curricula which were on file in catalogs in the University of Pittsburgh libraries.

Table I shows the credits and timing of organic and physical chemistry by the 89 schools. It also shows the number of years in the common curriculum and whether the chemical engineering curriculum is accredited by AIChE.

The following conclusions have been drawn from the data in Table I:

1. Nine schools provide no set curriculum, only guidelines and general course requirements.
2. Of the other 80, 53 make essentially a complete separation between organic and physical chemistry. The other 27 overlay these two areas; however, 13 of these stagger the courses somewhat. Only 14 schools out of 89 require both organic and physical chemistry at the same time completely.
3. Five of the 14 schools requiring complete overlap of organic and physical chemistry report a two year core sequence. The following table summarizes the "core" situation:

Years in Core	Number of Schools
0	43
1	35
2	7
3	2
4	2

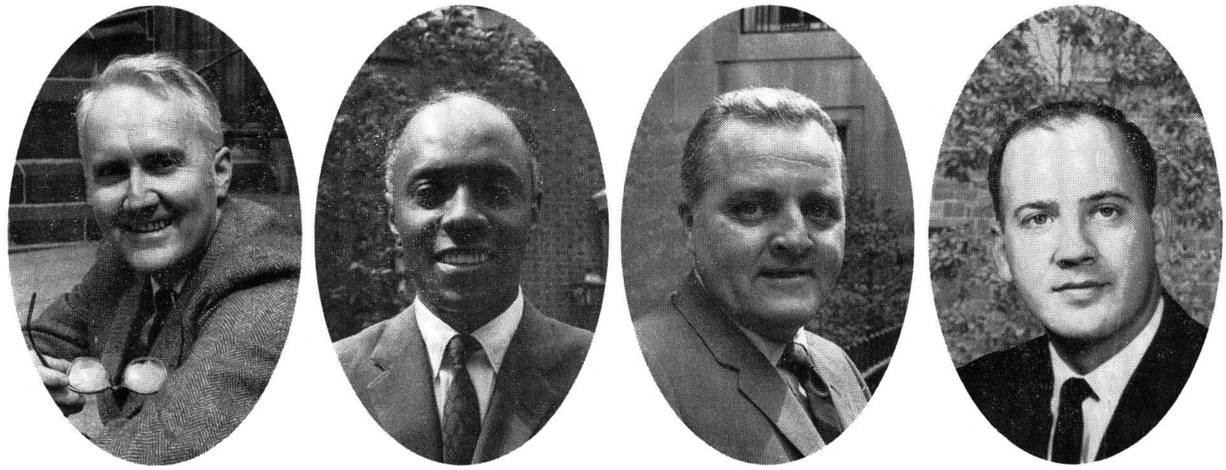
Those schools with two or more years in the "core" are clearly in the minority. The two schools with two core years without complete overlap in organic and physical chemistry accomplish this by (1) moving the first organic course into the second core year and (2) moving physical chemistry to the senior year.

4. Miscellaneous facts about organic and physical chemistry:
   (1) 19 schools offer physical chemistry below the junior year.
   (2) 44 schools offer organic chemistry above the sophomore year.
   (3) 13 schools go outside the sophomore and junior years to offer portions of organic and physical chemistry.
   (4) Six schools teach some or all of the organic and physical chemistry courses in the Chemical Engineering Department. Only one of these schools lacks a Chemistry Department. □

TABLE I. CREDITS AND TIMING OF ORGANIC AND PHYSICAL CHEMISTRY IN 89 CHE CURRICULA.

Years in Core	Organic Chemistry F1	F2	S1	S2	J1	J2	S1	S2	5th	Physical Chemistry F1	F2	S1	S2	J1	J2	S1	S2	School	Accredited	
1			4	4										4	4			1	yes	University of Alabama (1970)**
			3	3										3	3			2	yes	University of Illinois at Urbana (1969-70)
					4	4								4	4			3	yes	University of Missouri at Rolla (1970-71)
		5																4	yes	University of Oklahoma (1970)
1					4	4							3	3	3			5	yes	Newark College of Engineering (1975)
				4*												3*		6	yes	University of Pennsylvania (1970-71)
			4#	4#										4#	4#			7	yes	University of Calif. at Berkeley (1969-71)
					3	5						3	2					8	yes	Cornell University (1970-71)
4																		9	no	Stevens Institute of Technology (1970-71)
			4*											4*				10	yes	Massachusetts Institute of Tech. (1969-70)
1			3	3										4	4			11	yes	University of Maine
					4	4									3	4	1	12	yes	University of Arizona (1970-71)
			4#	4#										4#	4#			13	yes	California Institute of Tech. (1970-71)
			5	3										5	3			14	yes	Kansas State University (1970-71)
			4#	4#										4#	4#			15	yes	Auburn University (1970-71)
	4	4												4	4			16	yes	Bucknell University (1971-73)
2				·4#	2#									3#	3#			17	yes	University of Calif. at Davis (1969-70)
1.5					3	3						3	3					18	yes	Case-Western Reserve University (1970-71)
1						5¢	5¢							4¢				19	yes	University of Cincinnati (1969-70)
1					3	3						3	3					20	yes	Clarkson College of Tech. (1970-71)
1			3	4										4	4			21	yes	Clemson University (1970-71)
1						4#	3#						5#	4#				22	yes	Cleveland State University (1970-71)
1					4	4						4	4					23	yes	Colorado School of Mines (1970-71)
			4	4										3	5			24	yes	University of Colorado (1970-71)
1					6	3						4.5¢	4.5¢					25	yes	Columbia University (1969-70)
				3¢	4¢						5.5¢	4.5¢						26	yes	Cooper Union (1970-71)
4									3#							3#	4#	27	yes	Dartmouth College (1970-71)
1				4	4									4	4			28	no	University of Dayton (1970-71)
					4#	4#								4#	4#			29	yes	Georgia Institute of Tech. (1969-70)
			4	4												4	4	30	no	Grove City College (1970-71)
1				3	3									4	4			31	yes	University of Idaho (1969-71)
1					4	3							4					32	yes	Illinois Institute of Tech. (1969-70)
1-1/3						4#									3#	4#	3#	33	no	University of Illinois at Chicago (1969-70)
1					3#	2#						4#	4#					34	no	Indiana Institute of Technology (1970-72)
1					4#	4#							2#	3#	2#			35	yes	Iowa State Univ. of Science & Tech. (1969-71)
			---5-----*									---3------*						36	yes	University of Kansas (1970-71)
			3	4										3	5			37	no	University of Kentucky (1970-71)
2					4	4								3	3			38	yes	Lafayette College (1969-70)
2					4	4									3			39	yes	Lamar State College of Tech. (1970-71)
1					5								3	4				40	yes	Lehigh University (1970-71)
1					3#	1#								3#	3#			41	yes	Louisiana Polytechnic Institute (1969-71)
				3	5									3	3			42	yes	Louisiana State University (1970-71)
1			4	4										4	4			43	no	Lowell Technological Institute (1970-71)
2					3	3								4	4			44	yes	Manhattan College (1970-71)
1			4	3¢										3	5			45	yes	University of Massachusetts (1969-70)
			4#	4#										5#	5#			46	yes	Michigan Technological University (1971-72)
			5#	3#									3#	4#	4#			47	yes	University of Minnesota (1969-71)
					4	4								4	4			48	yes	Mississippi State University (1970-71
1			4	4										4	4			49	yes	University of Mississippi (1970)
			3	3										4	4			50	yes	Montana State University (1970-72)
			5	5										5	5			51	yes	University of New Hampshire (1969-70)
1			4	4										4	4			52	yes	New Mexico State University (1969-70)
1			4	4										3	5			53	yes	New York University (1969-70)
1			4	4										4	3			54	yes	N.C. State Univ. at Raleigh (1968-70)
					5	5								5¢	5¢			55	yes	University of North Dakota (1970-72)
1						3	3					3	5					56	yes	University of Notre Dame (1969-70)
			3	3		2								3	5			57	yes	Ohio State University (1970-71)
			5	3									3	3				58	yes	Polytechnic Inst. of Brooklyn (1969-70)
1					4	3						3	4	1				59	yes	Pratt Institute (1970-71)
1			---8-----*									---9-----*						60	yes	Princeton University (1970-71)
3							3							3	3			61	yes	Rensselaer Polytechnic Inst. (1970-71)
1					4	4							4	4				62	yes	University of Rhode Island (1969-70)
2																		63	yes	Rice University (1970-71)
			5	5										4	4			64	yes	University of Rochester (1968-69)
1			3	3	2									5	3			65	no	Rutgers, The State Univ. (1970-72)
			---8-----*									---8-----*						66	yes	San Jose State College (1970-72)
3																		67	yes	University of South Carolina (1970-71)
1				4	4									3	4	1		68	yes	S.Dakota School of Mines and Tech. (1968-70)
			4											4	3			69	yes	University of Southwestern Louisiana (1969-70)
							2#	2#						2#	4#			70	yes	Stanford University (1970-71)
					4	3								4	4			71	yes	Syracuse University (1969-70)
1					4#	4#								4#	4#			72	no	Tennessee Technological Univ. (1967-70)
					2#	4#							2#	4#	1#			73	yes	University of Tennessee (1970-71)
2					4	4										4	4	74	no	Texas A & I University (1970-71)
1			4	4										4	4			75	yes	Texas A & M University (1970-71)
			4	4										4	4			76	yes	University of Texas (1968-70)
			4#	2#										4#	4#			77	yes	University of Toledo
				5#	5#								5#	5#				78	no	Tri-State College
1			---*											---*				79	yes	Tulane University (1971-72)
			4	4										4	3			80	yes	University of Tulsa (1970-71)
			3#	2#										4#	5#			81	yes	University of Utah (1970-71)
1			3	5										4	4			82	yes	Vanderbilt University (1970-72)
				1	3									4	4			83	yes	Washington State University (1970-72)
2					4#	2#								3#	3#			84	yes	Wayne State University (1970-71)
			4	4										4	4			85	no	W.Virginia Institute of Tech. (1970-71)
			3	5										4	5			86	yes	University of Wisconsin (1967-69)
1				4	4							4¢			4			87	yes	Worcester Polytechnic Inst. (1970-71)
					3	3								4	4			88	no	University of Wyoming (1970-71)
			---3--*											---4*				89	no	Yale University (1970-71)

¢ taught by Ch.E. Dept; # quarter system. Credits approximate only; *student plans own program. Suggestion only but prerequisites and course series may lock student into "normal" program; **Year of catalog or curriculum.



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