ChE curriculum

A 15-MONTH MS CHEMICAL ENGINEERING DEGREE PROGRAM FOR BS CHEMISTS

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FOR A NUMBER OF YEARS students graduating with a bachelor's degree in chemistry have found themselves facing rather poor employment prospects. Often students who desire a career in applied chemistry enter chemistry programs in four-year colleges and smaller state universities where no ChE curriculum is offered in order to be close to home or, perhaps, the tuition is lower. Traditional chemistry curricula cannot satisfy their needs. In order to achieve their real desires many of these students should be in a ChE program. Some ChE departments are developing special programs to offer a form of graduate ChE education to chemistry graduates [1, 2].

A few years ago the ChE Department at Brigham Young University (BYU) became aware of this dilemma faced by chemists as increasing numbers of applications for admission to graduate ChE programs were received from dissatisfied BS chemists. Under normal circumstances such applicants could not be admitted directly to our graduate ChE program because they lacked appropriate undergraduate ChE background training. This meant that for a BS chemist to obtain a MS degree in ChE, two academic years were required plus a summer for research and thesis writing. The first academic year was devoted to elementary undergraduate subjects. This is essentially the approach taken by Texas Tech [2], and is what Cussler [1] refers to as a remedial program. The prospect of two full additional years of school frequently served as a deterrant and few students undertook such a program.

A NEW APPROACH

WE DECIDED TO DEVISE a program which would shorten the time required for a BS chemist to obtain a MS degree in ChE without sacrificing quality or soundness of training. We saw such a program both as an opportunity for chemistry graduates to gain a masters degree in ChE and as a service to many surrounding-area four-year college chemistry departments by providing a way for their industrially-oriented students to gain the further training they needed and desired. We also recognized it as a potential source of good first year graduate students to supplement the regular class of new ChE graduate students.

In order to maintain quality and a fundamental basis for such a program the chemist must be taught fluid mechanics, heat and mass transfer,

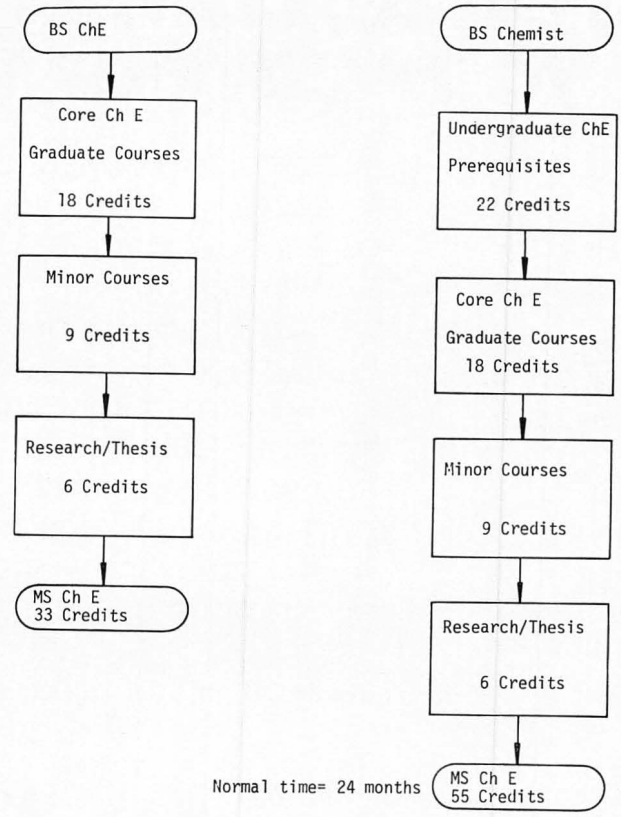
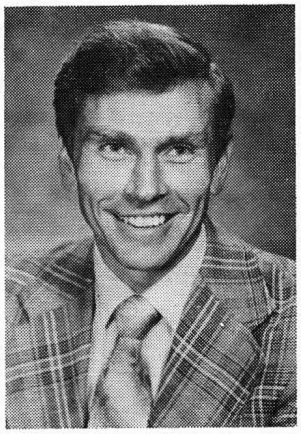


FIGURE 1. Flow chart for traditional MS degree program starting from BS degrees in Chemical Engineering and Chemistry (Remedial Track).



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John Oscarson graduated from BYU in 1968 then did graduate work at the University of Michigan 1971-74 after serving in the military. His interests are transport phenomena and separation. He has taught the summer course the three years it has been offered. (R)

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and separations technology, as well as kinetics, plant design and process synthesis and control. This training must be at the same level that is normally given regular ChE undergraduates who enter the graduate courses so that the chemists can successfully compete with ChE's.

The traditional MS degree course outline for a BS ChE and a BS chemist following the remedial track are illustrated in flow chart form in Figure 1. Clearly the problem for the chemist lies in the 22 semester hours of remedial undergraduate ChE prerequisites. These consist of: 1) a three-semester, 9-credit-hour series in unit operations (fluid mechanics, heat and mass transfer, and separations technology) spanning the junior year and part of the senior year of the undergraduate curriculum; 2) a two-semester, 4-credit-hour unit operations laboratory taught in the senior year; and 3) a three-credit-hour course in kinetics and reactor design and a six-credit-hour series of concurrent two credit-hour courses in plant design, process synthesis, and process control taught in the senior year.

In February 1976, the university granted the ChE department permission to undertake a new program which allows properly prepared BS chemists to obtain a MS degree in ChE in the normal 12 months plus one summer, or 15 months. The way this is accomplished is illustrated in flow chart form in Figure 2.

The key to shortening the time frame for the BS chemists lies in two modifications of the traditional program: (1) a special preparatory unit operations class, and (2) the minor. We recognized that chemists in their BS program take additional advanced level courses in chemistry, and sometimes physics and mathematics, beyond the usual physical chemistry requirement at which undergraduate ChE's normally stop. Most graduate students in ChE take their 9-credit-hour minor requirement in a "supporting field" arrangement. In this situation the minor courses may be drawn either from a single department or from a number of departments, and may range from upper division undergraduate to graduate courses in the supporting departments depending upon the student's preparation and degree of specialization.

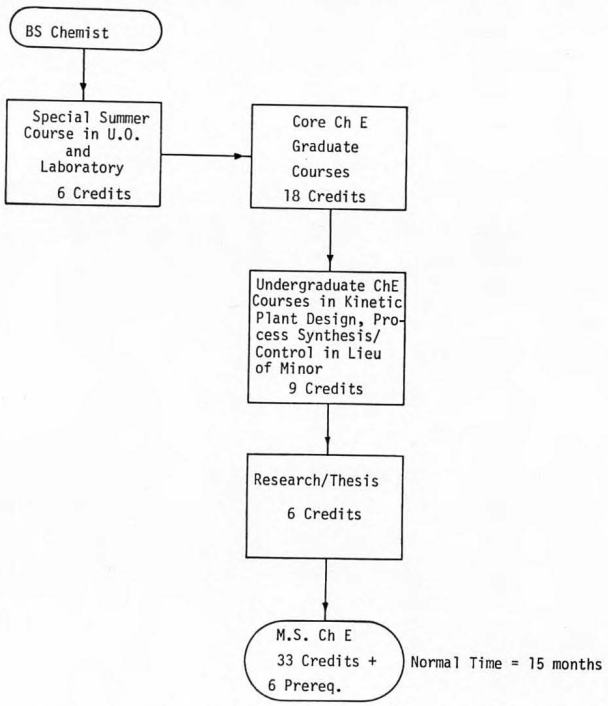

FIGURE 2. Flow chart for special MS degree program for well-prepared chemists.

We decided to devise a program which would shorten the time required for a BS chemist to obtain a MS degree in chemical engineering without sacrificing quality or soundness of training.

In developing this program we had to face the problem of what to teach a chemist to bring him "up to speed" in a short period of time. . . .

Thus, the advanced level chemistry and other technical courses usually taken by a senior chemist are generally equivalent to the supporting field minor frequently taken by a graduate ChE.

We decided to replace the usual 9-credit-hour minor requirement with 9 credit-hours of senior-level ChE courses formerly required as prerequisites (see Figure 1). Specifically, the courses chosen for this purpose were undergraduate kinetics, plant design, process synthesis, and process control (the latter two being open to both undergraduates and graduates).

This left only the unit operations and laboratory sequences to be dealt with. To cover this material we introduced a special 8-week, 6 credit-hour course taught from June through August which all entering BS chemists must take as a prerequisite to their graduate program. This special high-intensity course, which is described in more detail below, gives chemists the conventional unit operations course and laboratory all in one massive dose. This course is considered a remedial undergraduate preparation which must be passed before a chemist actually enters the M.S. program.

SPECIAL SUMMER CLASS

ENTRY TO THE NEW MS program must be through the special summer class. Chemists must also be properly prepared by having had a 3 credit-hour course in ordinary differential equations and a beginning course in FORTRAN programming as undergraduate students. If a chemistry student has not had these prerequisites, he or she must take them as remedial provisional requirements in addition to the usual graduate load. This usually necessitates an additional semester of work.

TABLE 1
MS Course Outline for BS ChE Student

COURSE NO.*	CREDITS FALL	WINTER	SP/SU
672, 673, 676	3	3	3
675, 681	3	3	
677	1		
691R	1	1	
699R	1	2	3
Minor Electives	3	3	3
	12	12	9

*See Table 4 for explanation of course numbers

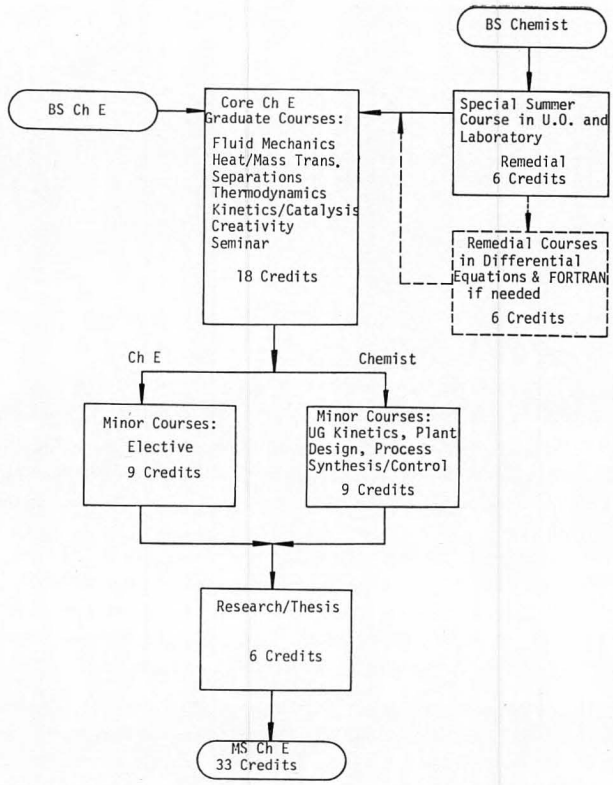

FIGURE 3. MS ChE degree program compatible with either a BS ChE or BS Chemistry degree. Normal time is 12 months for BS ChE student, 15 months for BS Chemist (may take 19 months if not prepared in math and computer programming).

With the introduction of the special summer course and some slight modifications in the way in which some of the core graduate courses are taught and sequenced to better accommodate both types of entering students, we have finally devised the MS program outlined in Figure 3. This flow chart shows that the program is compatible with either a BS ChE or BS Chemistry degree as a starting point. Table 1 shows the typical course outline followed by the BS ChE student. Table 2 shows the corresponding course distribution taken by the properly prepared BS chemist. Table 3 shows a typical course outline for a BS chemist who requires remedial mathematics and computer work. Table 4 gives a brief description of each of the courses listed by number in the previous tables.

Some concern has been expressed [1, 4] that students graduating from programs which at-

tempt [1, 2] to retrain chemists may not really be ChE's. We believe that we have successfully coped with and overcome this objection in our program. A chemist who successfully completes our program will graduate having had precisely the same *graduate* ChE course work and thesis experience obtained by any undergraduate ChE who completes the regular MS degree program. The chemist will also have had the complete senior year ChE curriculum as well as the junior year unit operations and about half of the senior year unit operations lab courses. He will have had equal physics, mathematics, and general education training and superior chemistry training. The place where a difference occurs is that the chemist will not have had the usual undergraduate courses in electrical circuits and engineering mechanics. To this extent they are slightly less broadly exposed to engineering than the usual ChE undergraduate. We do not perceive this as being a critical deficiency. We believe that chemists who graduate from our program are adequately trained in ChE and can be viewed essentially as MS ChEs with a strong minor in Chemistry.

TABLE 2
MS Course Outline for
Properly Prepared BS Chemistry Student

COURSE NO.*	SU	CREDITS FALL	WINTER	SP/SU
693R	6			
672, 673, 676		3	3	3
478, 681		3	3	
677		1		
675		3		
691R		1	1	
464, 550, 551			6	
699R		1		5
	6	12	13	8

*See Table 4 for explanation of course numbers.

RECRUITING AND FINANCING

AN ESSENTIAL ELEMENT for the success of a program such as ours is the recruiting effort. In order to generate a reasonable size class, we initiated recruiting activities at all four-year colleges in the state of Utah and a few in selected neighboring states. Personal visits are made to chemistry departments where junior and senior undergraduate chemists are interviewed and the program is presented and explained. In order to present the program effectively, we prepared a slide presentation which describes career opportunities in the chemical industry. The presentation outlines the differing roles of the chemist and the ChE, presents current job offer statistics and starting salary data for both, and outlines the BYU special program. This lecture is presented to both junior and senior chemistry majors, usually in a physical chemistry class. The usual response of chemistry department chairmen, especially in smaller schools, has been to request that it also be presented to freshman chemistry classes as a career-guidance service. This we have done. In addition to these activities we mail notices to a large number of chemistry departments and individual students as listed in the ACS lists of students recommended for graduate work.

TABLE 3
MS Course Outline for
BS Chemist Requiring Remedial Math/Computer Work

COURSE No.*	SU	FALL-1	WINTER	SP/SU	FALL-2
693R	6				
675		3			
673, 676, 672			3	3	3
478, 681		3	3		
677					1
691R		1	1		1
464, 550, 551			6		
699R				3	3
Math 321		3			
CS 131		3			
	6	13	13	6	8

*See Table 4 for explanation of course numbers.

All participants in the special summer class are expected to provide their own financial support. Our experience with all classes taught to date indicates that this is not a deterrant factor. The ChE department faculty decided that this special summer course should also serve as a screening mechanism to sift out marginal students. Therefore, all students entering the summer program are considered to be provisional students and are not admitted to full degree seeking status until they successfully pass the special course with a grade of B or better. Once a student successfully passes the special summer course, he is admitted

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TABLE 4
Brief Course Descriptions

COURSE NO.	DESCRIPTION
464	Undergraduate plant design
478	Undergraduate kinetics
550	Process Synthesis
551	Process Control
672	Advanced Fluid Mechanics
673	Heat/Mass Transport
675	Advanced Thermodynamics
676	Advanced Separations
677	Creativity
681	Advanced Kinetics/Catalysis
691R	Graduate Seminar
693R	Special UO Course for Chemists
699R	MS Research/Thesis
CS 131	Elementary FORTRAN Programming
Math 321	Ordinary Differential Equations

to full degree seeking status and is treated exactly as any other graduate student. He is fully eligible for all forms of department financial aid.

An administrative concern for any program such as this is its cost to the university. Some programs [1], because of the heavy use of scholarship subsidies, auxilliary text material production, and administrative and faculty costs are relatively expensive. Our experience to date has indicated a much lower cost for our program. Because no student financial aid is given, the principal costs are for recruiting, which is nominal, and faculty and administrative costs. This program costs the ChE department something between $5000 to $6000 per year.

BACK TO BASICS

IN DEVELOPING THIS program we had to face the problem of what to teach a chemist to bring him "up to speed" in a short period of time so that he could successfully compete with ChE undergraduates in the advanced level courses. One possible approach, used by Carnegie-Mellon [1], is to give the chemists a brief introduction to each topic in the full undergraduate curriculum without going into detail or depth in any topic. In addition to lack of substantive depth, this approach creates the additional problem of what to use for text material [1] necessitating the writing and reproduction of large amounts of hand-out materials, thus increasing costs. We chose not to take this route. Rather, we elected to develop a substantive course in unit operations in which the chemists could learn the fundamentals of fluid mechanics, heat and mass transfer, and separation technology at a level and depth commensurate with undergraduate ChE's. The special summer course which we have developed seems to accomplish this objective.

A second objective which this course must meet is to help the chemist overcome what might best be described as a "culture shock", which all seem to experience in making the transition from chemistry to ChE. Chemists do not approach problems in the same manner as do ChE's. The heavy emphasis on quantitative results, the need to make assumptions, and the necessity for manipulation of multiple systems of units are foreign concepts for most chemists and mastery of these skills is difficult for all and mildly traumatic for some. Most students generally accomplish this transition reasonably well during the first weeks of the course.

In order for the course to succeed both the instructor and the students must reconcile themselves to the idea that it requires full-time effort. Students are not allowed to register for any other courses and are permitted to engage in part time employment only in extreme circumstances.

The course is structured around the classical unit operations approach and closely follows the text *Unit Operations of Chemical Engineering*, 3rd Edition by McCabe and Smith [3]. This text has proved quite satisfactory for this course. Having a text available greatly helps the students and also reduces the overall costs of the program by eliminating the need for reproducing large amounts of handout materials. Table 5 contains a listing of the chapters and topics from the text which are covered during the course and the approximate amount of time spent on each. Short chapters are covered in one day while longer chapters require two days. As can be seen, all the material on fluid mechanics and heat transfer in

We further believe that graduates of our program can legitimately classify thesmselves as ChE's because they have had exactly the same graduate coursework and thesis experience that regular ChE's do plus most of the technical undergraduate experiences. They are not just "warmed over" chemists.

sections 2 and 3 of Reference three, and most of the material on mass transfer and separations processes in section 4 is covered. Section 5 on grinding, mixing and solids handling is omitted.

The class consists of from two to three hours of lecture each day starting at 8:00 A.M. Three or four homework problems are assigned each day which require most of the student's time following the lecture classes. The instructor frequently assists students in his office during this time. At 4:00 P.M. the class meets together with the instructor and a graduate teaching assistant for a problem solving session that may last from one to two hours.

Starting about the third week of the course one day a week is devoted to the laboratory. On lab day no lecture is held and students spend six hours in the lab. They see this as a welcome break from the routine of lectures and problem sessions of the other four days. In the laboratory the students are divided into two-man teams. Each team performs one experiment in each of the three subject study areas: fluid mechanics, heat transfer, and separations. Since there are a large number of experiments available in the BYU undergraduate unit operations lab and a small number of student teams, no two teams perform the same experiments. Each team is required to report orally to the combined class on the experiment which they performed and to prepare written reports which are graded. This activity allows all students to become acquainted with each experiment and provides a good experience for the students preparing and giving the reports. This schedule is maintained for the remainder of the eight-weeks course.

TABLE 5

Topics Covered in Class

SUBJECT	NUMBER OF 2-3 HR. LECTURES
Material & Energy Balances	1
Fluid Statics	1
Introduction to Fluid Flow	1
Flow of Incompressible Fluids in Ducts	2
Flow of Compressible Fluids	1
Flow Past Immersed Bodies, Settling, Packed Beds, etc.	1
Pumping & Metering of Fluids	1
Mixing and Stirring Fluids	1
Conductive Heat Transfer	1
Fundamentals of Heat Transfer in Fluids	1
Heat Tranfser to Fluids w/o Phase Change	2
Heat Transfer to Fluids with Phase Change	1
Radiative Heat Transfer	1
Heat Exchangers	2
Evaporation	1
Phase Equilibria, Diagrams, etc.	1
Equilibrium Stage Operations	1
Distillation	3
Leaching & Extraction	1
Multicomponent Distillation	1
Gas Absorption	1

. . . chemistry majors can successfully complete our program . . . and are well qualified to go on to doctoral degree programs in ChE at reputable schools or go to work in industry.

RESULTS OF THE PROGRAM

THE PACE OF THE summer course is very demanding but student morale is generally quite high and the students develop a sense of achievement. Most students negotiate the chemistry to engineering culture shock quite well and are able to compete successfully with their regular ChE colleagues in subsequent graduate courses. About 80% of those starting in the program successfully complete it. To date we have had four graduates of this program accepted into doctoral ChE programs—two at BYU and two at other schools. Offers of employment have been about as frequent and as lucrative as those to regular ChE graduates. Indeed, some recruiters, noteably from pharmaceutical companies, have specifically asked to see Biochemistry majors in the program. Thus, it seems that the students who complete this program are about as well qualified as regular MS ChE graduates to compete in the graduate school and job markets.

As with all programs, we have encountered some problems. The most serious problem is keeping the students from feeling overwhelmed during the summer course. Because of the large volume of material presented very rapidly, the students feel like they are always running behind trying to catch up. This problem is best handled by encouragement from the instructor and generous amounts of personal help. The class is limited in enrollment to 10-12 students so that the instructor can give the necessary amounts of personal help.

Another problem arises when students enter the program without prior background in ordinary differential equations or FORTRAN computer programming. This does not particularly cause problems during the special summer course. The

difficulties arise in the graduate fluid mechnics and thermodynamics courses which follow. As a result, poorly prepared students must follow a more protracted schedule shown in Table 3. About half of our students have encountered this problem. We are attempting to counteract this difficulty through our recruiting program by counselling junior chemistry majors who anticipate seeking admission to our program to take courses in ordinary differential equations and FORTRAN computer programming before they graduate.

Our experience to date indicates that chemistry majors can successfully complete this program for an MS ChE degree and are well qualified to go on to doctoral degree programs in ChE at reputable schools or go to work in industry. We believe that the combination of the intensive special unit operations course coupled with the full undergraduate senior year of ChE courses as a "supporting fields" graduate minor makes our program somewhat unique among the several programs now in existence. We further believe that graduates of our program can legitimately classify themselves as ChE's because they have had exactly the same graduate coursework and thesis experience that regular ChE's do plus most of the technical undergraduate experiences. They are not just "warmed-over" chemists. In our view this program represents a marriage of the best parts of both worlds. □

REFERENCES

1. Cussler, E. L., *Chem. Eng. Education, 11*(4), 176 (Fall 1977).
2. Bethea, R. M., Heichelheim, H. R., and Gully, A. J., *Chem. Eng. Education, 11*(4), 181 (Fall 1977).
3. McCabe, W. L., and Smith, J. C., Unit Operations of Chemical Engineering, 3rd. Ed., McGraw-Hill, New York, 1976.
4. Cussler, E. L., private communication to authors, 1977.

AIChE NEWS

FIRST WORLD CONFERENCE ON CONTINUING ENGINEERING EDUCATION

April 25-27, 1979 Mexico City

For complete program and registration information write to: John P. Klus, University of Wisconsin—Extention, Department of Engineering & Applied Science, 432 North Lake Street, Madison, WI 53706

ChE news

MARATHON RUNNERS

Lloyd Berg reports that at least two chemical engineering department heads completed 26-mile marathons during 1978. Lloyd Berg of Montana State ran the Governor's Cup race in Helena and Tom Owens of North Dakota University completed the Grand Forks run. Any other department heads? Any other chemical engineering faculty?

LARSON SELECTED AS CHAIRMAN

The Department of Chemical Engineering at Iowa State University is pleased to announce that Dr. Maurice A. Larson has been selected as the new Department Chairman. Dr. Larson is currently Anson Marston Distinguished Professor in Engineering and has been a member of the Chemical Engineering faculty at Iowa State since 1958.

ChE books received

Continued from page 19

Solar Cooling and Heating: Architectural, Engineering and Legal Aspects, edited by T. Nejat Veziroglu. Hemisphere Publishing Corp., Washington, D.C. 20005. Three Volumes, $120

The Chemical Bond, by J. N. Murrell, S. F. A. Kettle, and J. M. Tedder. Wiley, New York. 1978. 310 pages, $27.

Recent Developments in Boiling and Condensation, by E. R. F. Winter, H. Merte, Jr., and H. M. Herz. Verlag Chemie International, New York. 1977. 106 pages paperback $16.

Thermal Effluent Disposal from Power Generation, edited by Zoran P. Zoric. Hemisphere Publishing Corp., Washington, D.C. 20005. 1978. 375 pages, $40.

Two-Phase Transport and Reactor Safety, edited by T. N. Veiroglu and S. Kakac. Hemisphere Publishing Corp., Washington, D.C. Four volumes, 1416 pages.

Fuel Economy of the Gasoline Engine, edited by D. R. Blackmore and A. Thomas. Halsted div. John Wiley, New York. 1977. 268 pages.

Two-Phase Flows and Heat Transfer, edited by S. Kakac and F. Mayinger. Hemisphere Publishing Corp., Washington, D.C. Three volumes, 1469 pages.

Engineering Fundamentals: Examination Review, 2nd ed., by D. G. Newnan and B. E. Larock, Wiley—Interscience, New York. 1978. 503 pages, $21.95

Combustion and Incineration Processes: Applications in Environmental Engineering, by W. R. Niessen. Marcel Dekker, New York. 1978. 384 pages, $35

Integrodifferential Equations and Delay Models in Population Dynamics, by J. M. Cushing. Springer-Verlog, New York. 1977. 196 pages $8.30

Technical Data on Fuels, ed by J. W. Rose and J. R. Cooper, 1977. Halstead Divison of J. Wiley, New York. 343 pages $70