APPENDIX B.
COURSES USING THE PROCESS DESIGN GAME

1) ChE 690 Technical Project Management	Fall 1973; Fall 1974 Seniors and graduate students in chemical engineering
2) EG 125 Introduction to Engineering	Fall 1973 Freshmen students in chemical engineering
3) ChE 530 Engineering Analysis for Non-Majors	Spring 1974 Junior and senior students in chemistry life science, mathematics and electrical engineering
4) ChE 667 Special Topics Course	Winter 1974 Session A group of senior students in chemical engineering
5) Engineering Analysis for Chemists	Summer 1974 A course for industrial chemists—a group from the Swiss chemical and pharmaceutical industry
6) Introduction to Engineering	Spring 1975 A course to introduce high school juniors to engineering
7) Engineering Analysis for Chemists	Spring 1975 A course for industrial chemists—a group from the Organic Chemicals Department of the E. I. DuPont Company

ChE book reviews

CELLULOSE AS A CHEMICAL AND ENERGY RESOURCE

5th Symposium of Biotechnology and Bioengineering
Plenum, New York. ($25.00)

Reviewed by Charles Walter, University of Houston

The 5th Symposium of Biotechnology and Bioengineering was about "Cellulose as a Chemical and Energy Resource." The organization of the topics includes contributions about "The Substrate," "The Enzyme System," "The Process," and "The Product."

"The Substrate" is cellulose. In this section there is a weak chapter about cellulose economics which reflects confusion about scientific matters and relies heavily on meaningless figures (for example, the figures about cellulose conversion into protein or ethanol, or alcohol conversion into adenesine triphosphate).

The remainder of the section about "The Substrate" is highly recommended. An excellent introductory statement establishes that the greatest portion of what we call waste cellulose is not really "waste" at all, and that processes utilizing the substrate must be economically viable. This theme is continued in a later chapter dealing principally with agricultural "wastes." Other chapters in this section contain excellent discussions of the relationship between energy input and energy yield for cropping systems and a specific cost analysis for producing plant biomass on a hypothetical plantation. This analysis leads to an optimistic estimate of about $10/ton of dry biomass, or $ .65/10^6 Btu. The important chapter by Diaz puts into prospective however, that even if cellulose were obtained from "waste" sources that were "free," the substrates used as chemical or energy resources would be considerably more expensive due to the high processing costs involved. Bassham's chapter provides an excellent sketch of the overall energetics of cellulose production in green plants, including a discussion of the merits of C-4 plants versus plants without this extra CO_2 - fixing pathway, and an estimate of the photosynthetic efficiency expected for this process. The number Bassham arrives at is 5% which is about half the often-quoted maximum theoretical efficiency for photosynthetic processes.

"The Enzyme System" is cellulase but the worthwhile contribution to this section of the volume is about the action of H_2O_2/Fe(II) on cellulose—a process which obviously could lead to significantly lower costs for commercial cellulose digestion. This, together with the fact that many cellulolytic organisms apparently secrete little or no cellulase, is a compelling argument for more research on the H_2O_2/Fe(II) system and brown-rot fungi and less emphasis on isolated and reconstituted enzyme systems. The deep-seated prejudice that compels many biochemists to isolate biomolecules from their three-dimensional, functional environment and study their properties in an irrelevant setting dominates most of the other papers in this section. Judging from comments made in other sections of the volume (for example, "Too much of our existing knowledge about cellulose hydrolysis has been derived from studies with purified raw materials" by E. L. Gaden on page 161) many of the sym-

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ChE DEPARTMENT: Penn State

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of importance in petroleum refining has been an active area for Ron Danner and Tom Daubert. Three editions of the American Petroleum Institute's *Technical Data Book—Petroleum Refining* have been produced in the department since the project was originated by Merrill Fenske and Walter Braun in the early '60's. Further activity includes the very difficult problem of identifying readily measurable parameters for the characterization of petroleum fractions which are very complex and poorly defined mixtures. Ron and Tom have also been working on the development of generalized corresponding states methods for polar fluids and the measurement and correlation of gas mixture adsorption on solid surfaces.

- **Dynamics**

Bob Kabel, after developing a thorough understanding of the kinetics of certain acid ion exchange catalyzed reactions, has been using these reactions as a vehicle for understanding reactor dynamics. In particular, he has experimentally demonstrated the potential of forced periodic reactor operation to improve catalyst selectivity. Al Engel has experimentally demonstrated the use of forced cyclical operation of stirred tank reactors to maintain transients in a neighborhood of an unstable steady state. Al's recent simulation work has shown that cyclical operation of a distillation column may produce energy savings approaching fifty percent of steady state operation for the same separation.

John Tarbell has been working on non-linear stability theory for reaction and reaction-diffusion processes. Liapunov's direct method provides the theoretical framework and irreversible thermodynamics provides an untapped source of Liapunov functions. Bifurcation phenomena, especially bifurcation to periodic and chaotic orbits are also being investigated.

In conclusion, we must emphasize that the success of our research programs has been and will continue to be a direct consequence of the dedication and perseverance of our graduate students. □

ChE letters

SUMMER ENERGY-RELATED INSTITUTES

Sir:

Oak Ridge Associated Universities will present four energy-related institutes for college faculty this summer. The institutes sponsored by the U. S. Department of Energy, DOE, are designed for faculty who teach or plan to teach energy-related courses. A limited number of stipends are available. The deadline for applying is March 31, 1978. The institutes to be presented are:

ENERGY PRODUCTION AND THE ENVIRONMENT
June 19-July 7, 1978
ENERGY OPTIONS FOR THE FUTURE
July 10-21, 1978
ENERGY CONSERVATION:
THEORY AND PRACTICE
July 10-28, 1978
COAL PRODUCTION AND UTILIZATION
July 31-August 11, 1978

Full information about the summer institutes and application material may be obtained from the Professional Training Programs, Manpower Education, Research and Training Division, Oak Ridge Associated Universities, P .O. Box 117, Oak Ridge, Tennessee 37830.

Roger J. Cloutier

BOOK REVIEW: Cellulose

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posium participants were aware of the shortcomings of the enzyme studies. The results presented in these papers lack the raison d'être of the H_2O_2/Fe(II) studies, and it is not evident that they can be justified on the basis of Good Science. The chapter about lignin-degrading reactions is interesting, but very speculative. The conclusions that more data are needed and that they should relate to whole organisms rather than isolated organisms, are certainly valid. The summary statement about cellulase enzymes at the beginning of this section is well done, but it is sufficient.

"The Process" is the conversion of cellulose and lignocellulosic materials into glucose (or some other, equally useful product). The excellent chapter about physical and chemical features of cellulose and lignocellulosic materials would be better placed in the section about the substrate. This chapter is informative, and with its emphasis on susceptibility for the process, certainly not out of place where it is. The chapter that follows, also intended to be about the relationship between structure and process susceptibility, is a classic example of the ridiculous following the sublime. To be convinced of the former, one needs only to refer to the last figure and the claim that the different shapes of the curves drawn therein are significant. The chapter on pre-treatment and its

discussion are not only excellent, but they also are concerned with an economically important aspect of the process. The chapter about enzymic saccharification of woody wastes is useful, but since it deals with only the *T. viride* cellulase, prospects for its ultimate commercial applicability are limited. Individuals with experience using enzyme kinetics will find the chapter about the kinetics of cellulose hydrolysis harmless, but others might not be so fortunate. Even if, as commonly happens in studies of homogeneous solutions of single enzymes, the assumptions (some unlisted, none justified) used to derive the well known equation for the reaction rate and its integral do not cause serious problems, the methods of data analysis (see Figures 2 and 3) used in this chapter probably will. The chapter about the economics of the enzymic conversion of cellulose to glucose is of pedagogical value. However, the very optimistic parameters used in the model (for example, raw material costs are estimated to be nil, and the recovery figure for active catalyst to be at least 3 times what one would expect on the basis of most experimental findings) not only strain the imagination, but probably invalidate even the order of magnitude of the cost estimate.

"The Product" is . . . .? The important point of the summary statement is that a diversity of products will strengthen the market for cellulose. The chapter about potentially useful products develops this idea in considerable detail. The products discussed include fuels, food and organic chemicals. There is also an interwoven discussion of product and process feasibility which includes the questionable suggestion that the old Fischer-Tropsch synthesis might be commercially useful now or in the near future. The excellent chapter on fuel gas production includes a survey of solid waste disposal technology followed by a description of a bioconversion process for the production of methane from waste cellulose. The discussion includes results obtained from a computer model and process optimization. These results indicate a 3-fold energy return in the form of $\$2/10^6$ Btu methane in a $22 million plant capable of processing 1000 tons/day of solid waste. As in some of the previous cost estimates discussed at the symposium, these figures seem optimistic, in part because they do not include adequate research and development costs that would be necessary to iron the kinks out of a new process. The other chapters in this section are also highly recommended. The chapter about the acid-catalyzed hydrolysis of waste illustrates that the conversion of pre-heated material to glucose can be modeled as an isothermal plug flow reactor with a residence time in the range of 20 to 30 seconds. This chapter, as well as the interesting ones by Miller and Finn discuss the bioconversion of cellulose-derived glucose into ethanol.

As mentioned above, two of the shortcomings of the cost estimates appearing in this volume are that they tend to be based on optimistic parameters, and that they seldom reflect sufficient R & D costs to achieve a smooth-running industrial process. Another shortcoming of these estimates is that they do not take into account the interactive economic forces that make these models so highly nonlinear. For example, ethylene and ethanol are interconvertable, but at present ethanol is made from ethylene because the cost of ethylene plus processing to ethanol is less than the price of ethanol available by other means. But what if ethanol could be made from cellulose at a price that was sufficiently below the current price of ethylene? The price of cellulose would probably increase, and that would cause the price of ethanol to go up. Furthermore, artificially-set oil prices would probably be decreased, and that would cause the price of ethylene to go down. Both factors would tend to favor the production of ethanol from ethylene even when conditions were reached which in present cost analyses would seem to favor the production of ethylene from ethanol. Thus, it would seem that the models used in some of the cost projections are incomplete.

But perhaps the models are nevertheless as good as they need to be. Although the editor is to be complimented for the speedy assimilation of the manuscripts, even a year renders many of the relevant cost analysis parameters hopelessly obsolete. One wonders, for example, if Miller's projected doubling of ethylene costs by 1975 occurred, and if so, what has happened to the cost of this important chemical now in 1978, three years later. Furthermore, there is considerable variation in the numerical values of parameters that don't depend on time. For example, if individuals at the same symposium disagree by 20% about the cellulose content of "most wood," refining the mathematical model might not improve the modeling result.

It seems to me that most of the cost predictions in this volume should be treated as a very rough, first approximation. Since large financial investments usually require more reliable forecasts, it is doubtful that much action will (or should) be taken on the basis of these analyses, at least in the near future. □