Model 2

The difference equation for Model 2 is of second rather than fourth order. Its solution is

$$\Psi_n = \frac{FH\lambda^n - J}{F^2H\lambda^N - J}$$

where

$$H = 1 + fF + s$$

$$J = F + fF + s$$

$$\lambda = \frac{H[F(1+f)(1+f+s)+J(Ft+fFt+st+s+2fs)]}{J[t(1+fF+s)^2+f^2F(1+2s)+(1+s)^2(1+2f)]}$$

Only a few calculations were made for Model 2 because it became evident that at entrainment rates in the range of validity of the model (probably f and s of 0.1 or less) the entrainment has little effect on extraction. When equilibrium is reached in the mixer, both models give the same result. For other cases the extent of extraction is always greater for Model 2 because of the mass transfer in the settler.

USE OF THE ANALYSIS AND CONCLUSIONS

This analysis will find utility in the design of settlers, for it suggests that settlers other than after settlers are sometimes over-designed. If there are no complicating consequences of entrainment, such as the formation of stable emulsions, entrainment rates as high as 10% are rarely consequential.

The results will also be useful for interpreting experimental data. In particular if an extractor has low efficiency, measurements of entrainment from the settlers will establish whether the low efficiency is caused by the entrainment or by poor mass transfer in the mixers.

The major conclusion to be drawn from this work is that high entrainment rates have relatively little effect on the efficiency of mixer-settler extractors. When such extractors have poor efficiency, it is therefore more likely to be caused by low mass transfer rate than by entrainment from the settlers. This suggests that efficiency of some mixer settlers might be improved by operating the mixers at higher rates provided that (1) there occurs no deleterious effect such as the formation of stable emulsions and (2) the capacity of the after settlers is adequate. If after settlers are not used, then improvement might be obtained without excessive entrainment in the effluents by increasing the mixing rates in all but the first and last mixers.

NOTATIONS

E_e = entrainment or settler efficiency, N_o/N

E_m = Murphree efficiency in distillation or mixer efficiency in extraction, $Ft/(1 + Ft)$

E_{mo} = over-all efficiency of a column with no entrainment [see Equation (19)]

E_o = over-all efficiency, N_t/N

F = extraction factor, mQ_f/Q_s

f = fraction of Q_f entrained in the solvent phase from a settler

Kav = product of a mass transfer coefficient and the interfacial area per mixer

N = number of actual stages

N_o = number of stages to effect a given extraction with no entrainment

N_t = number of theoretical stages

Q_f = flow rate of feed phase to extractor

Q_s = flow rate of solvent phase to extractor

s = fraction of Q_s entrained in the feed phase from a settler

t = Kav/Q_s

x = concentration of solute in feed or raffinate phase

y = concentration of solute in solvent phase

Ψ_n = dimensionless concentration of feed phase, $(x_i - x_n)/(x_i - my_i)$

Ψ_N/Ψ_{NO} = $\Psi(s, f, F, t, N)/\Psi(0, 0, F, t, N)$

Γ_n = dimensionless concentration of solvent phase, $(y_n - y_i) Q_s/(x_i - my_i)Q_f$

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CHEMICAL ENGINEERING PROGRESS SYMPOSIUM SERIES ABSTRACTS

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The *A. I. Ch. E. Journal* will publish, from time to time, abstracts of the articles appearing in the Symposium Series volumes. Recently published volumes are abstracted below.

CHEMICAL ENGINEERING EDUCATION—ACADEMIC AND INDUSTRIAL, Vol. 55, No. 26, 1959.

Evolution of the Unit Operations, Warren K. Lewis. The technological achievements of the profession in America during the last half century have been impressive. No small part of the credit is due to the training the young engineer has received. The emphasis on basic science has given the understanding of inner mechanisms and the analytical ability to foresee and plan for ultimate results. The unit operations approach has stimulated technical imagination and has shown the way to the transfer of experience acquired in one area to others which sometimes seemed unrelated. Moreover, making it possible to reduce coverage of detail without sacrifice in breadth has resulted in training in greater depth. The foundations laid by the educational pioneers have proved sound and dependable. **Development of Chemical Engineering at the University of Michigan,** Donald L. Katz. The sixty years of chemical engineering education are surveyed for the influences that have dominated the curriculum. As in most schools, at Michigan the birth of this new branch of engineering was due largely to teachers of chemistry. The association of the faculty with industrial processes drew the teacher into research on engineering problems and provided the stimulus for new engineering courses. The evolution of the curriculum is traced from one consisting primarily of chemical technology through the development of engineering science to the current program, characterized as the era of design. New concepts now under discussion are likely to be introduced very soon. **Present Status of the Unit Operations,** William Licht. The concept of the unit operations is a unique American contribution to the development of the chemical engineering profession. The coinage of the neat phrase *unit operations* about 1915 served to distinguish concisely the area of activity of this kind of engineer in industry, helped him to become freed of his earlier identification as a composite mechanical-engineer-chemist, and speeded recognition of the new young branch of engineering as an independent discipline in its own right. It also became the focal point around which the teaching of chemical engineering was organized for many years. **A Definition of Chemical Engineering and a Few Implications Regarding Chemical Engineering Education,** Seymour Calvert and H. Benne Kendall. With a definition of engineering and a concept of the process of thinking and learning, a few implications have been drawn as to the nature of the "average" engineer and the most effective method for teaching him. The essential parts of an undergraduate curriculum have been considered and a conclusion drawn that not much significant variation can be made in its content. **The Engineering-Science Approach in the Teaching of Chemical Engineering,** W. H. Corcoran. The goal of the engineering-science curriculum is to prepare the chemical engineer for the broadest approach to his professional career. After training in engineering science the chemical engineer should have the ability to begin fruitful work in research, development, or production in any industry concerned with physical and chemical changes. The broadest foundation will be found in mathematics, physics, and chemistry; engineering-science training may be considered as directed primarily toward the development of facility in the application of those sciences to the basic problems of chemical engineering. **Graduate Work in Chemical Engineering,** Kenneth A. Kobe. The only quantitative measure of graduate work in chemical engineering in the United States is the number of degrees granted. The approximate ratio of 19:4:1 for B.S.:M.S.:Ph.D. degrees shows the extent to which engineers enter graduate work. The fact that five sixths of the engineering schools give the master's degree and half give the doctorate makes it worthwhile to examine the requirements that the various schools have for their graduate degrees. **Chemical Engineering Education at the Graduate Level,** A. B. Metzner. This paper is based on the hypothesis that graduate education should not consist of simply an extension of undergraduate work to mask any deficiencies therein, but instead should provide a rigorous and mechanistic analysis of the fundamental scientific factors underlying the processes of engineering interest. Proper analysis of a research problem would constitute the core around which the program would be built. Recognizing the diversity of the industrial opportunities to which chemical engineers may be attracted, a well-rounded department offering graduate education must be able to provide research opportunities in a number of different areas. Work in these specialties, however, should never degenerate to descriptive discussions of present (or past) industrial processes and should consist primarily of instruction offered by the appropriate science departments rather than by engineering instructors. **A Look into the Future–Technical Study Course Sponsored by the Local Section,** A. G. Gibson, W. R. Manning,

(*Continued on page 6S.*)

(*Continued from page 4S.*)
and R. E. Pyle. The study-course program is a practical method of stimulating the engineer to continue his education. It offers the section member a low-cost medium whereby the chemical engineer can continue his professional development throughout his industrial career. **A Curriculum Organized by an Industry and a University,** David H. Morgan. One notes today a great and growing interdependence of American social institutions. Industry, business, labor, education, government, all have a common concern—lifeblood in the form of new personnel to move forward in a rapidly changing social order. As a case in point, this paper submits curricula organized, built, and operated by the joint efforts of industry and education. **An Advanced Training Program of a Specialized Industry,** John J. Merrill and Harrison M. Lavender. Three principal areas for continuing education in chemical engineering in industry are discussed: the technical, supervisory, and management areas. Each of these areas is presented in terms of its functions, its educational needs, and the methods used for providing the necessary education. From this description of the present situation the authors go on to discuss trends and to forecast briefly future requirements for continuing education. Much of the material presented is developed directly from successful practices of the Standard Oil Company of California and its research subsidiary, California Research Corporation. It is believed that the material presented applies quite generally to most large oil companies and with some limitations to most other processing industries employing large numbers of chemical engineers. **Education for Engineers—Training for Mobility,** Carl H. Elliott. The story of Socony Mobil's continuing education of chemical engineers is one which varies from location to location. The laboratory story is different from the story in the refineries, and the story in the research and development laboratories varies from that in the technical service laboratory. A look into the future reveals the complex and increasingly broad role that engineers will play in a scientifically oriented, industrial society. The author's beliefs in this direction stem from his recent experiences, first on the staff of the technical extension division of a major engineering school where the work was quasiinstructional and quasiconsultative in the fields of management organization, human relations, and industrial psychology, and second from present observations of the engineer in field locations and also from the over-all Socony Mobile view.