Book Reviews

Nuclear Chemical Engineering. By Manson Benedict, Thomas Pigford, and Hans Levi. McGraw-Hill Book Company, New York (1981). \$37.95.

Nearly 25 years have passed since Benedict and Pigford first published *Nuclear Chemical Engineering* as part of the McGraw-Hill series in nuclear engineering. The second edition of this important work represents considerably more than an updating of graphs and figures. As the authors note, during the past two decades, nuclear power systems have become important contributors to the energy supply of most industrialized nations. Indeed, the first commercial nuclear power plant in the United States began operation *after* the first edition of *Nuclear Chemical Engineering* was published. While in large measure the fundamentals of nuclear chemical engineering have changed little, the sophistication of the industry, the environment in which it exists, and the prognosis for its continued development have changed drastically. The second edition builds on the still appropriate fundamentals and emphasizes these in the context of significant process development and industry growth.

The first four chapters of the text are devoted to a review of the basic nuclear processes and the use of these processes in commercial-type applications. The basic concept of the commercial nuclear fuel cycle is developed early and affords a proper context for the more specialized chapters that follow. Setting a general tone for the second edition, these early chapters present fuel cycle features and processing characteristics more definitive in nature than the earlier edition. The somewhat idealized discussion and analytical treatment given to the basic power reactor nuclear processes, the combination of factors characterizing reactor performance, and even the traditional chemical engineering unit operation of solvent extraction as applied to both fuel processing and fuel reprocessing are very well done and quite appropriate. A very good balance of theory and practice as well as specific points versus general ideas has been achieved. Finally, it should be noted that in rounding out the introductory chapters, the authors give only the briefest mention of fusion energy and leave little doubt that the present text will be devoted to the fission cycle and the attendant chemical engineering that supports it.

Following the introductory material, Chaps. 5 through 9 deal concisely but not superficially with some of the important materials that feed, house, and result from the fission processes generally used today. Uranium and thorium are of prime importance in today's nuclear power plants and as such rightfully deserve the expanded discussion given. Mining, refining, and conversion to fuel forms for these two naturally occurring feedstocks are presented along with solution chemistry aspects of special importance to the nuclear fuel cycle.

In the case of uranium (Chap. 5), a somewhat disappointing aspect is the lack of completeness in the discussion of uranium processing. For example, Eldorado and British Nuclear Fuels, Ltd. are not mentioned in the UF_6 production area; similarly, Mallinckrodt and National Lead are not cited in the area of making metal. Likewise, in the referencing there are no notations, for example, to Smiley et al., or to Hanford's calciner development, or to more detailed compendia such as Harrington and Ruehle. Finally, there is a lack of coverage on production of UO_2 for fuel elements.

Chapter 6 deals with thorium in much the same manner as Chap. 5 deals with uranium. In both instances, a concise and straightforward approach is taken. As would be expected on the basis of current power reactor status, the thorium discussion is much shorter. Regrettably, however, the significant status of development of the thorium cycle, its synergism with respect to the uranium-plutonium cycle, and the special features that attend this "second" fuel cycle are not addressed to any significant extent.

Zirconium and hafnium are considered together in Chap. 7, and the overall treatment is straightforward and well done. The amount of text devoted to these materials is perhaps excessive relative to other important issues in the general area of nuclear chemical engineering.

Chapter 8 is a summary of the properties of irradiated fuel. It provides several illustrative tables of spent fuel data for different reactor systems and, incidentally, follows so logically from the mathematical base provided in Chap. 2 that the material could have easily been presented there.

Plutonium and other actinide elements are discussed in Chap. 9. As with the other "material characterization" chapters, this chapter is concise and methodical in its presentation of these very important factors in the fission fuel cycle. In combination with Chap. 8, this chapter forms a good background and lead-in to Chap. 10, which tackles the very important back-cycle task of reprocessing.

Fuel reprocessing must address a complicated collection of often competing concerns. Certainly the recovery of fuel value is an issue, but so are such diverse concerns as equipment operation and maintenance, spent fuel cooling time, and treatment of effluents—all of these and more, each in the context of economics and specific fuel cycle requirements. From the nuclear chemical engineering aspect, perhaps no other single portion of the fission cycle is so challenging as fuel reprocessing. Much more could easily be devoted to this general topic, especially as regards the added challenge of breeder fuel reprocessing, spiking, coprocessing, and a host of other "current" endeavors in research and development. Nevertheless, the authors have presented a very good discussion of the basics involved. Aspects of selected fuel cycles, each with its own peculiarities of processing and waste generation, and even the very important concern for criticality in reprocessing is noted. In many respects, the fuel reprocessing chapter provides a natural lead into the chapter on radwaste management.

As presented in Chap. 11, radioactive waste management includes a broad range of activities and concerns. The appropriateness of this is well founded. Sources of wastes, their types and amounts, the processing strategies, the storage and/or disposal of the wastes, and a host of more specific and technical concerns only hint at the effort and understanding that has gone into this general issue. The summary-type discussion presented here will serve a useful role in the education of the somewhat enlightened student as well as a concise reference for the practitioner.

The final three chapters of *Nuclear Chemical Engineering* focus on isotope separation. By way of introduction, a brief and somewhat incomplete overview of principal separation methods used for the more important isotopes is presented in Chap. 12. The vocabulary and broad relationships relevant to separating units, differential stage separation, and basic cascade theory are adequately introduced along with selected but important concepts such as the ideal cascade, minimum reflux, minimum stages, equilibrium time, inventory, and separative work.

Light element isotope separation is considered in Chap. 13. Following some basic and historical information on deuterium separation, the various processes for hydrogen isotope separation are discussed: distillation of hydrogen; distillation of water, including some design/hardware-oriented "working" equations; electrolysis; and various exchange processes, with emphasis appropriately placed on the Girdler-sulfide process. This chapter concludes with a brief discussion of the lithium exchange process and only a mention of separation processes for the carbon, nitrogen, oxygen, and sulfur isotopes. This imbalance and the omission of any significant discussion on boron isotope separation are of academic, but not practical, concern.

The most extensive chapter in the text is the final chapter. The subject of uranium isotope separation is introduced on an historical note and with an overview of current (as of about 1978) projects. Following this introduction, a reasonably complete treatment of gaseous diffusion is presented. The principle and history of gaseous uranium diffusion are discussed, and equipment used by the U.S. and the French gaseous diffusion programs is described. Barrier flow theory and relationships for separation and mixing efficiency are provided. Stage design aspects are discussed in context, with working equations and examples, including economic calculations. The gas centrifuge process is dealt with in a similar fashion, but more limited to separative performance relationships for the machine itself. The aerodynamic methods of Becker and UCOR are treated only briefly, as are mass and thermal diffusion.

The treatment of the advanced isotope separation processes is quite limited. The two laser processes are described, with the discussion of atomic vapor laser isotope separation (the process recently selected by the U.S. Department of Energy for further demonstration) largely following that provided in a 1977 Jersey Nuclear-Avco Isotopes paper and the discussion of molecular laser isotope separation drawn largely from the early work of Jensen and Robinson at Los Alamos National Laboratory. It is granted that classification and the developing nature of these processes preclude any in-depth discussion. However, the fact that there is no significant basic theory provided, no scoping equations, and no first-order technical treatment of the key issues and directions is a weakness that cannot be easily attributed to the status of classification or of technology at the time of writing. Added to this is the omission of the plasma separation, chemical exchange, and ion-exchange processes, which are all receiving attention today as they have been for the last five or more years. With this weakness, the book ends on a dated note, and some of its utility as a text or reference work for fuel cycle engineers of the future is accordingly diminished.

The fact that some topics are dated and/or too incompletely dealt with does not, however, take too much away from the book's considerable utility. Its assets—including generally good coverage of material, adequate references, and good problems—far outweigh any deficiencies noted by these reviewers. It is a tour de force, an obvious labor of love by the authors, and a welcome and highly recommended addition to the fuel cycle literature.

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Radioactive Decay Data Tables: A Handbook of Decay Data for Application to Radiation Dosimetry and Radiological Assessments. By David C. Kocher. Technical Information Center, Oak Ridge, Tennessee (1981). 221 pp. $13.75.

This useful handbook is an updated and expanded version of a previous report by the same author[1] and is one of several similar compilations[2,3] of radioactive decay data that have appeared in recent years. This new compendium contains recommended decay data for ~500 radionuclides of interest in nuclear medicine and fusion reactor technology or of potential importance in routine or accidental releases from the nuclear fuel cycle.

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[1]D. C. KOCHER, "Nuclear Decay Data for Radionuclides Occurring in Routine Releases from Nuclear Fuel Cycle Facilities," ORNL/NUREG/TM-102, Oak Ridge National Laboratory (1977).

[2]L. T. DILLMAN and F. S. VON DER LAGE, "Radionuclide Decay Schemes and Nuclear Parameters for Use in Radiation-Dose Estimation," Pamphlet 10, Society of Nuclear Medicine, New York (1975).

[3]M. J. MARTIN, "A Handbook of Radioactivity Measurements Procedures," Report No. 58, p. 306, National Council on Radiation Protection and Measurements (1978).