Book Reviews

Fusion Reactor Physics: Principles and Technology. By Terry Kammash. Ann Arbor Science Publishers, Inc. (1975). 495 pp. $29.50.

Fusion research began as a secret subject, but starting with its declassification in 1958, there was a prodigious growth in the literature of plasma physics and fusion. In the early 1960's, several books were published on controlled fusion, for example, those written by Rose and Clark, by Glasstone and Lovberg, and by Artsimovich. Before reviewing Kammash's book, it is instructive to look back briefly through these earlier books to see how these older ones have stood the test of about 15 years of time. Each of these earlier books has about half its pages devoted to explaining elementary plasma physics; the remainder of the text describes plasma devices and experiments. The basic sections still read well, although better and more comprehensive treatments of plasma physics have subsequently been published. The sections on experimental devices look now somewhat ancient; these parts seriously show their vintage. Nonetheless, it is interesting to note how many of the ideas and concepts were in existence 20 years ago.

Most of the 1960's was devoted to modest-size experimental devices and a rather serious effort to obtain understanding of basic phenomena and getting the plasma physics straight. A great deal (in fact, a remarkable amount) of progress was made, and by the early 1970's government program administrators believed that sufficient knowledge was in hand to permit starting a major development program in fusion power. Not everyone was in agreement with this assessment of the state of knowledge. Nonetheless, attention (i.e., funding) was directed toward fusion power reactor designs, and development was started on some of the technology that fusion reactors concepts appeared to need. As the first fusion reactor designs began to unfold, it became more evident that the technology problems that confront the fusion reactor designers are very formidable and that solving them may require an effort equal to or exceeding that which has already been devoted to understanding plasma physics. Whether the fusion concepts chosen, namely, tokamaks, mirrors, and pellet-inertial schemes, really will evolve into practical fusion-power-producing reactors remains to be seen.

It is, however, clear that during the next quarter of a century, several fusion concepts will be tested in devices whose size, character, and cost are similar to that of a modest-size power station. To help with this development task, we need to educate and train a new group of engineers who can effectively translate the best fusion physics concepts into practical, reliable, and hopefully economically competitive power sources. To assist in this engineering development task, Kammash has written *Fusion Reactor Physics: Principles and Technology*, which was published in 1975. It is a 495-page book written at the level used by good seniors or early graduate students of science and technology. This book has a style and content best suited for those with a nuclear engineering background. It contains sufficient material for a two-semester course. The author has tried to choose those topics and concepts which he feels are most essential to understanding fusion power developments, at least as they appeared in the early 1970's. An elementary knowledge of plasma physics will prove helpful in deriving maximum benefit from this book, but it is not essential. Reflecting the literature in this field, a mixture of MKS and cgs units are used, depending largely upon the source material.

The first chapter is introductory, providing motivation and displaying the character of fusion power. It briefly discusses different fusion reactions, fuel cycles, estimates of fusion reactor conditions, and a very brief introduction to mirror and toroidal magnetic traps, as well as the concept of plasma stability. The author briefly speculates on where we are in the development of fusion power, perhaps being influenced a bit too much by government planning documents, and he lists some of the major technological problems that lie ahead. This is one of the places in this book that already seems dated. The experiments mentioned (namely, 2X-II, T-3, and ST) are no longer the touchstones they once were. The most recent reference in this book is June 1975, and a great deal has happened since then. Whether or not one is optimistic concerning fusion energy, let alone a particular concept for fusion power, may depend on whom you speak with, the latest experimental results, recent federal fiscal facts or rumors, and whether our form of government has the capability to carry out a program whose time scale is several decades.

The second chapter provides further fusion fundamentals, such as simplified fusion reactor energy balance and ignition calculations, the Lawson criteria, radiation loss-rate formulas, and burnup estimates. The text then settles down to a detailed treatment of selected technological subjects. These include a chapter on fusion reactor neutronics (38 pages), several chapters on supplementary heating, e.g., neutral beams (50 pages), relativistic electron beams (26 pages), rf (26 pages), and adiabatic compression (20 pages).

Reactor dynamics and control are discussed in Chap. 8 (27 pages), and some environmental aspects of fusion are described in Chap. 9. Here, for example, emphasis is given to direct conversion schemes related to some older mirror reactor concepts. The interesting and very controversial subject of fission-fusion hybrids is given a rather brief treatment in the six pages that make up Chap. 10. Chapter 11 is an introductory treatment of inertial (pellet) confinement. The major technical problem of development of very high power, high energy (10^{15} W, 10^{6} J) lasers needed for fusion power is hardly mentioned. Some of the hydrodynamic problems associated with implosion compression are discussed, but the physics complexities are avoided. Whether or not such schemes can be made practical and economically competitive is left to the reader's imagination. Chapter 12 discusses radiological aspects of fusion reactors such as the expected radioactive material inventory in a given fusion plant and the shutdown afterheat problem.

Chapter 13 devotes 37 pages to design aspects of toroidal and mirror reactors. This chapter was, unfortunately, written just prior to the publication of the first generation of complete reactor designs developed at the national laboratories, the University of Wisconsin, and General Atomic Company. Therefore, the book does not really display any real reactor design study results, but rather presents early parameter studies used to help determine a reactor operating point. Several generations of different reactor designs have now been developed, and the subject of reactor design has considerably advanced over that briefly begun in this text.

Chapter 14 (53 pages) treats radiation damage to fusion reactor materials; it is a very good introduction to this important topic. The remainder of the text treats rather briefly some heat transfer problems and discusses the differences between some reactor concepts.

I particularly liked some parts of this interesting book, i.e., the chapters on neutral beams and the radiation damage of materials. There are, unfortunately, some pages completely filled with equations and formulas that will put off all but the most devoted reader, and some of the figures employed print too small to read. Treating a rapidly changing subject is difficult, and Kammash has done a creditable job in bringing much material together. Where his text treats fundamental physics and nuclear science, it is at its best.

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About the Reviewer: Robert A. Gross is professor of engineering science and a member of the Mechanical and Nuclear Engineering Department at Columbia University, where he founded the Plasma Laboratory in 1960. Following completion of his graduate studies at Harvard in 1952, Dr. Gross was first engaged in aerospace and combustion research. He is a Fellow of the American Physical Society and of the American Institute of Aeronautics and Astronautics.

Determination of Uranium and Plutonium in Nuclear Fuels. By Herbert Sorantin. Verlag Chemie, Weinheim (1975). 288 pp.

This book is the fifth volume of the series "Kernchemie in Einzeldarstellungen," and, following a general trend, the third to be written in English. At the time of writing this book (1972), the author indicated economic reasons in addition to safety (criticality) considerations as the main motivations for high-precision analysis of fuel (chemical composition, content of fissile material, nuclear purity control). In the meantime, the price of nuclear fuel material has increased, its availability has become restricted, and the prospects of a "plutonium economy" have become a public concern and target for opponents of nuclear energy. A worldwide nuclear material safeguard system is being established. All these reasons justify a compilation of our knowledge on the determination of the most important components of nuclear fuel, namely, uranium and plutonium.

The author did not intend to present a handbook of fuel laboratory practice but rather a review of possibilities (~3000 references). The book is divided into two main parts, covering the analysis of nonirradiated fuel (or "fuel elements," as indicated in the corresponding chapter headings) and irradiated fuel (elements), respectively. The chapters of both parts follow a similar, although not completely identical, scheme, e.g., sampling, dissolution, separation, and determination of the elements or their compounds. Nondestructive examination of fuel elements is included. Special emphasis is given to the most important methods of separation (solvent extraction, ion exchange, extraction chromatography) and of elemental determination (volumetric, electrochemical, spectroscopic), as well as to techniques for the measurement of isotopic abundance and burnup.

In general, the problems are clearly outlined; many solutions are offered, and their principles and application limits are described. Schematic illustrations of many instrumental methods are presented, and an overwhelming amount of information is summarized in the tables. The reader is frequently referred to reviews, and references are compiled at the end of each subchapter.

A few comments might be made: The division of the book into analyses of nonirradiated and irradiated fuel (elements) is not always consistently followed: Although the "nonirradiated fuel" part includes sampling, purity control, dissolution, fabrication control, and nondestructive examination of plutonium-containing (fast) reactor fuel, the separation and determination methods (more than one-third of the book) are restricted to uranium; on the other hand, plutonium analysis is discussed mainly in connection with irradiated fuel.

Readers might have difficulty in finding the established practical methods among the large number of possibilities described, might be misled by the sometimes unreflected use of "fissionable" and "fissile," of "fuel" and "fuel elements" as synonyms, or might be confused by a lack of correspondence between some references in the text and in the lists. There are a few misprints in formulas and nuclide symbols and misspellings of authors' names. The reviewer must admit that he found it difficult to understand a sentence in the jacket text: "Since the price of the spent nuclear fuel is a significant item in cost calculations, it is important to know the content of the fission products both in non-irradiated and in burnt-up fuel elements."

This book of Sorantin can be recommended as a comprehensive review of the literature on uranium and plutonium determinations up to the early 1970's. It is most helpful in the hands of experienced workers, used to "Selected Methods," to remind them of other analytical possibilities and some of their pitfalls.

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