NUCLEAR SCIENCE AND ENGINEERING: **14**, 319–321 (1962)

Book Reviews

Uranium Dioxide: Properties and Nuclear Applications. Edited by J. BELLE, U. S. Government Printing Office, Washington, D. C., 1961. 726 pp., $2.50.

There has been a growing tendency over the last few years for the appearance of what have been called "non-books"—collections of papers, often only faintly related, between hard (or, as in this case, paper) covers. Whether such a set is a coherent and useful entity depends essentially on the knowledge and skill of the contributors; but perhaps even more directly on the ability of the editor to coordinate the assorted points of view, stylistic approaches, and basic interests. Knowledgeable readers of the recent technological literature will immediately recall some notable failures among such books, brought about by a lack of understanding of the needs of the reader, and perhaps an indifference and lack of compassion for his motivations in buying and reading the book.

The publication under consideration here has, happily, achieved an excellent balance of all these factors. Belle has performed an outstanding service to members of the nuclear profession (if such there is) in bringing together this collection of nine papers by some forty different authors. The book has been assembled and edited with considerably more care than is usual, and the preparation, properties, reactions, irradiation behavior, etc. of UO_2 are all quite adequately covered. Although six of the senior contributing authors are from Belle's organization, the Bettis Laboratories, as is perhaps to be expected, the book is not completely dominated by a parochial and purely local point of view—a persistent and unfortunate problem which has manifested itself in many publications.

In discussing a material like uranium dioxide, which is of great fundamental interest as well as rather direct engineering application, there is always the problem of achieving a judicious balance between science and technology. With UO_2, there have of course been a large number of strictly engineering tests, whose extension and application to systems other than the one for which they were conducted is somewhat questionable, if not impossible. It is a tribute to Belle's editing, as well as the restraint and good judgment of his contributing authors, that material of this sort is at a minimum in this book. In the highly personal opinion of this reviewer, the ratio of science to engineering here is an excellent one.

Among the many sections, the chapter by Ben Lustman on "Irradiation Effects in Uranium Dioxide" may perhaps be singled out for special comment. This is almost long enough (pp. 431–666) to be published as a separate monograph, and is a rather heroic attempt to bring order to a generally chaotic field. Lustman succeeds admirably in most cases; and where he finds an irreconcilable discrepancy (see p. 504, for example) he says so boldly and directly. Would that all research workers were as honest and frank!

There is room for some criticism of the book, however. It is primarily propaedeutic, a summary of past experience, in the U. S. Government laboratories. There has been little attempt to pass judgment on the validity of the information, and to separate the wheat from the chaff, in some chapters. There is only superficial and passing recognition of the major contributions that have been made by our foreign friends to UO_2 technology, the Canadians and British for example. (In fact, the only foreign contributor to the book is Ross, of Chalk River.) There is a strong orientation of the majority of the authors towards water-cooled reactors, and the reactions of UO_2 with other types of heat transfer media—sodium and CO_2, for example—are largely ignored. Occasionally, poor proofreading can be seen; on p. 71 we are told that certain UO_2 powders "are pyrophoric," and on p. 72, there is a sentence differing in its wording only in that now these powders "tend to be pyrophoric." On p. 125, the words "fissile" and "fissionable" are used without explicit definition[1] in a rather grossly arbitrary fashion.[2] On p. 200, in the equation, there is no doubt that the $e^{-b}P$ as printed should really be e^{-bP}. Occasionally, an almost incredible bit of naïveté and lack of familiarity with the literature pops up. For example, in speaking of solid state diffusion on p. 313 the Dienes relation (1950) between D_0 and the energy of activation for the process is mentioned, but there is no indication that the writers knew that a correlation probably equally valid was presented by Dushman and Langmuir[3] in 1922. The treatment of gaseous diffusion on p. 528 will also bring a weary and tolerant smile to the face of the sophisticated reader. On p. 436, shouldn't $\ln^2$ really be $\ln 2$? The rather barbarous bit of jargon, the word "knockon," used on p. 525 for example, seems not only to lack elegance, but to be completely equivalent in meaning to the rather older and better-established word "collision." My associate at Vallecitos, T. J. Slosek, must certainly wonder how his name could be misspelled at least five times (pp. 643, 647-twice, 666, and 722) when it was undoubtedly copied right from the title page of a report.

But these are admittedly minor difficulties that will certainly be corrected when the second edition of this book is prepared. For the time being no worker in the nuclear field

---

[1] See *Nucleonics* **19**, 4 (1961).

[2] "When *I* use a word" Humpty-Dumpty said in rather a scornful tone, "it means just what I chose it to mean—neither more nor less."

—Lewis Carroll, *Alice Through the Looking Glass*, Ch. 6.

[3] S. DUSHMAN AND I. LANGMUIR, *Phys. Rev.* **20**, 113 (1922).

can afford to have this excellent compilation missing from his bookshelves. After all, where else among books printed in English can you buy 726 pages, illustrated, on glossy coated paper, for only $2.50?

LEO F. EPSTEIN
General Electric Company
Vallecitos Atomic Laboratory
Pleasanton, California

(Editor's Note: Leo F. Epstein is with General Electric's Vallecitos Atomic Laboratory in Pleasanton, California. He has been engaged in nuclear activities for the past fifteen years, ten of them at KAPL, the last five in California, almost all of this time on some aspect of UO_2-fueled reactors.)

The Metallurgy of Hafnium. Edited by DONALD E. THOMAS AND EARL T. HAYES. For sale by Supt. of Documents, U. S. Government Printing Office, Washington 25, D. C., 1960 paperback, xii + 384 pp., $1.50.

As "The Metallurgy of Zr" neared completion (1955), the reviewer wrote to his co-editor, Ben Lustman, suggesting the publication of a companion volume on Hf. Ironically, some seven years later he finds himself in the critic's chair appraising the product of two of his valued friends and coworkers, Drs. Don Thomas and Earl Hayes, of long service with Westinghouse and the Bureau of Mines, respectively.

The editors have worked in the field of the so-called reactive metals since the late 40's and have played key roles notably in the early development of Zr and Hf. The reviewer has had the privilege of working closely with both, particularly during his Naval Reactors Branch sojourn (1950–55). The reader will appreciate the fact that these circumstances have made this review a special challenge.

In general the volume is very well written and adequately provided with tables and figures, table of contents, name and subject indices, etc. Some of the photographs are hazy but this is not a serious disadvantage. Unfortunately, the text contains many errors, most of which again are not serious; these will be taken up with the editors privately. In keeping with the tradition of this series the volume pays lavish tribute to its sponsor.

The volume can stand independent of the Zr field—almost! Herein lies one of the differences of philosophy between the editors and the reviewer. Although the text purports to avoid duplication, the paralleling with Zr is extensive. Many sections lean heavily on the book's progenitor "The Metallurgy of Zirconium."

Hafnium has been described, and not entirely facetiously, as "like zirconium—only more so!" Since the similarity between the two metals is great, the reviewer would have preferred to use Zr technology as a foundation and emphasized the differences in the Hf volume. The reviewer notes in this volume a persistence concerning the alleged difficulty of separating Zr–Hf. Let's be realistic—certainly the problem is less severe than that of separating isotopes—or columbium from niobium! Also, of special interest are the disruptions to the "natural" sequence of Ti–Zr–Hf as in the case of stress–strain (page 233), corrosion (page 282), reactivity (page 329). To this we might add the tetrachloride vapor pressures.

Chapter 1 should be limited to actual applications. The largest of these is nuclear, of course, and judging by recent articles by John Theilacker, Kermit Anderson, and others, the treatment here is hardly adequate. Regarding the nonnuclear applications, reference to Schwarzkopf and Kieffer's "Refractory Hard Metals" would show how little we know about a potentially valuable group of compounds. Based on Misch's electrolytic studies, the reviewer feels that Hf or its alloys might some day compete with Ta in the capacitor field.

Chapter 2, aided by process declassification, updates the Zr–Hf separations. The extraction methods are threatened by the Newnham disproportionation method (page 67), which was still under development last year at U. S. Industrial Chemicals Co. (*Chem. Eng. News*, **39**, 71 (1961)). Another challenger, now dormant, may be Bromberg's (duPont) distillation method (page 65). When will someone test A. F. Reid's fractional sublimation method on Zr–Hf separation? It is interesting to note that early discussions with Plucknett have been followed with patents (page 65).

Chapters 3 and 4 cover reduction and refining, respectively. A basic difference between Zr and Hf shows up dramatically here in the inability to use Hf sponge without refining. However, as was pointed out by the reviewer years ago, some cost savings can be effected by blending good sponge with X-bar made from poor sponge. One recalls Frank Block's (BuMines) study of pressure liquefaction which gave interesting results in $ZrCl_4$ purification and which might be tried for Hf. One's curiosity is aroused as to what the effect of the Petersen-Bromley film boiling method might be on HfI_4 dissolved in inert carrier salts. What if we replaced deBoer's filament with a levitated molten globule of Hf? The deBoer method is challenged by the electrolytic processes developed by Baker (BuMines) and Steinberg *et al.* (Horizons, Inc.). Also of interest here is Goldenberg's (NRL) Ti patent. Success in electrorefining will reflect in emphasis on electrowinning. And if the latter should succeed for Hf, can Zr be far behind?

Chapter 5 covers melting and fabrication; the electron beam melting section of Chapter 4 probably should have been included here. Chapter 6 covers what little is known about the alloys. Chapter 8 plods tediously through the analytical chemistry. Here, I start to miss Warren Blumenthal's "The Chemical Behavior of Zirconium."

Properties are scattered, with Chapter 1 covering nuclear, Chapter 7 physical, Chapter 9 thermodynamics. A better grouping or coordination would be desirable.

One of the most intriguing facets of Hf over the years has been the subtle interplay of supply–demand and yields in relation to supposed costs. A chapter on this area would have been most appropriate. Extending the prices quoted on page 8 the reviewer can add one serious industrial offer to produce X-bar at $1000/lb in exchange for residues at $1/lb (1950). The offer was, of course, rejected. However, material cost is but one factor; Hf rods must be compared with alternate rods on an over-all cradle-to-grave basis. Uses for spent Hf rods are not covered in the text.

The section on history which starts in the foreword and continues in Chapter 1 warrants a separate chapter. It is interesting that the recent history of Hf spanning hardly a decade can become so vague so soon. But between the lines of any tome lies many another story. The reviewer recalls flashes from the Hf panorama: The rows of drums of "useless" hafnium hydroxide stored at the Oak Ridge Y-12 plant. Alvin Radkowsky's initial skepticism over his re-