he developed several novel fabrication techniques for special control rods during this period.

The book begins with the usual Introduction as Chapter 1. Chapters 2 through 9 present information on properties of the commonly used control rod materials which would be useful to those engaged in fabrication of such rods. These chapters depend rather heavily on a well chosen system of references headed by Anderson and Theilacker on "Neutron Absorber Materials for Reactor Control" and selected papers from the early Symposium on Control Materials published in the September, 1958 issue of *Nuclear Science and Engineering*. (It might be noted that Mr. Ray was a strong contributor to both of these publications.)

Chapters 10 through 12 pay special attention to documentation of the fabrication technology. Chapter 13 deals with procedures for quality assurance of control rods. Since proper functioning of control rods is a critical factor in reactor safety, due attention to such quality assurance becomes a very important consideration.

The last chapter, numbered 14, contains the usual effort by authors to use a crystal ball and predict future developments. (It is this reviewer's experience that such guesses usually turn out to be wrong.)

An adequate index is provided. The usual difficulty was encountered in guessing as to which cubby hole the indexer had chosen in which to file a given item. Experience teaches, however, that such a guessing game must always be played with the index-writers of new technical books and in this case only reasonable ingenuity was needed to win the game. The conclusion was that if Ray put it in the book, Anderson could find it, generally without resort to thumbing, by using the index.

There are, as usual, some faults with the book. Principal among these are obvious errors in word selection, semantics or grammar which more careful editing should have eliminated. Typical of these is the lead-off sentence in Chapter 6. Quoting: "Cadmium was used to control the first self-sustaining nuclear chain *reactor* in the CP-1 reactor at the University of Chicago in 1942." Obviously Mr. Ray intended that the itallicized word be *reaction* rather than *reactor*. Also, there are some obvious errors of omission such as one in Fig. 74 on page 164. Here in a flow sheet depicting Leittens technique for making Eu_2O_3/stainless steel dispersions from elemental powders Mr. Ray has no iron in his stainless steel. This caused a bit of a semantic block and brought the reviewer into some confusion and worry when due search failed to reveal the missing iron.

A similar example of a sin of omission seems obvious on looking at Table 1 in Chapter 1. If samarium with its 13.8% of a single high-cross-section isotope is worth listing, why omit gadolinium with two high-cross-section isotopes totaling 30.4% of the naturally occurring mixture?

These faults, however, are not too serious, and certainly the volume deserves a place on the bookshelf of any nuclear materials engineer who has any serious interest in control rods, their development or production. Although directed toward the practicing metallurgist or engineer, the book can easily be read with benefit by advanced undergraduate students in engineering. Mr. Ray does not indulge in pedantry. Rather he assumes the stance of a good workman discussing a subject to which he has contributed with an audience of his peers. This reviewer can recommend the book to either the beginning engineer or the practicing technologist as a source of accurate information in the field of fabrication technology for control rods in nuclear power reactors.

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(About the Reviewer: Dr. W. Kermit Anderson is Consultant - Materials Engineering to the staff of the Materials Development Operation at the Knolls Atomic Power Laboratory. His interest in neutron absorber materials was first aroused during a search for high efficiency shielding materials while employed by the NEPA Project at Oak Ridge. This interest was maintained during employment at the Argonne National Laboratory and more recently at the Knolls Atomic Power Laboratory where this work has led to several publications in the field. These include joint contributions with J.S. Theilacker and others, including W.E. Ray, to writing and editing the book, "Neutron Absorber Materials for Reactor Control," published for the U.S.A.E.C. by the U.S. Government Printing Office in 1962.)

Materials for Control Rod Drive Mechanisms. By George A. Freund. Rowman and Littlefield, Inc., New York, 1963. 209 pages. Paperback $4.45; Hard cover $6.95.

Several years ago the Atomic Energy Commission contracted with the American Society for Metals for six monographs on metallurgy in nuclear technology. The present volume is the third in the series. The reader may note a similarity to the British Nuclear Engineering Monographs by Temple Press, Ltd.

The one word which best describes Freund's book is "concise". Eleven well-written chapters

cover the materials of the mechanisms which (paraphrasing p. 10) control the position or motion of the control rod by a suitable driving mechanism which has appropriate ranges of speed and change of speed.

The case history treatment of typical drive mechanisms is excellent. Analysis of the Dresden reactor difficulties drives home the hard lesson of thorough specifications, inspection, and testing. With reluctance we acknowledge our too-effective teacher — mistakes!

The various aspects of corrosion and wear are highlighted forcefully. The stress factor recalls peculiarities from the early MTR beryllium program. Thermal or mechanical shock of thin transverse extrusion sections revealed a strange "fibrous fracture" originating from casting defects. The extrusion defect, detectable by prolonged etching, led to sudden breakup of samples in extended corrosion tests. The prelude to cracking may involve "triggering" effects not readily measured and perhaps time does reveal all defects (pp. 94-96).

In keeping with the succinct text an acceptable minimum of tables, graphs and diagrams is provided. Several of the complicated diagrams are about as difficult to follow as are the sketches in U. S. Patents. Descriptions positioned on the page opposite to the diagram would be helpful (pp. 25, 26).

Chapter referencing is generally adequate and for good measure an extensive general bibliography (118 refs.) is provided. The latter would be much more useful if grouped according to subtopics. Specific mention should be made of the comprehensive volumes on reactor control by Mortimer Schultz (1955) and Joseph Harrer (1963). The Appendix covers composition and key properties of most of the materials in the text. For some alloys the reader may have to check sources such as Woldman's "Engineering Alloys". Based on the premise that a technical book cannot be overindexed the present one could use some reinforcement.

The book will be most useful to the small group of engineers having a general interest in control problems. The few specialists in this narrow field will find little that is new here. Antipodally, the reader of limited metallurgical exposure will face many problems of terminology, which would be greatly eased by a glossary. For this wider audience the glossary should include definitions which are now occasionally out of sequence in the text, or missing. One definition in particular which will not "sell" is the acronymic explanation of crud as "corrosion recirculation and ultimate deposition" (p. 62). Even dePaul avoided the once-popular "Chalk River unidentified deposit". In contrast to Freund's adjective "unglamorous", Webster refers to crud as a poetic variation of curd.

By way of background to this volume, we note that early STR (Nautilus) plans called for ANL to concentrate on reactor development and Bettis Laboratory on fabrication. The reactor field was then confronted with many problem areas, one of the most serious being that of the control drive mechanisms. Control, of course, is an important aspect of reactor safety which always holds precedence over economics or efficiency. Consequently, severe performance requirements are balanced against even higher reliability requirements. This situation was further complicated by weak corrosion-wear theory and even weaker data.

With this challenging setting, author George Freund joined ANL in 1950. In the ensuing eleven years he acquired an excellent perspective of various reactor problems which should serve him well in his present capacity as a consultant.

Credit for the "big push" in the development of control drive mechanisms for sodium and water reactors falls to the Naval Reactors Branch of the Atomic Energy Commission. Veterans of the STR-SIR projects will recall with trepidation the various control drive offensives launched from the shadow of the Washington Monument. The nursery, if not the birthplace of the Nuclear Navy (Wing 4 of Building T-3) reverberated with frequent frenetic "fire drills" which resulted in program accelerations seldom equalled and probably rarely surpassed in American industrial experience. Although heretofore largely slighted, our Naval annals may in due course acknowledge these significant aspects of life behind the zirconium curtain.

Of the above two reactor environments, the sodium problem is perhaps simpler. The Na-NaK Supplement (1955) of the *Liquid Metals Handbook* gives some clue to the extensive NRB programs on bearings development. The water environment is summarized more elaborately by Dominick J. dePaul's (Bettis Lab) *Corrosion and Wear Handbook*, TID-7006, (1957).

The latter is the principal source of inspiration for Freund's volume, as evidenced by frequent referencing. Sometimes dePaul is followed too diligently as in the questionable slope/intercept equation for effect of load on wear (p. 124). Of far greater interest would be the Archard and Hirst equation in which the specific wear rate is defined as the ratio of the volume of material removed to the product of the applied load and the sliding distance (*Proc. Roy. Soc.* A, 1956, Vol. 236; p. 397). A second equation incorporates the flow pressure of the softer material.

Compared to water and sodium, the gas and organic environments seem simple. We note

happily that helium is still inert. And this year saw the OMRE join the late LMFRE and HRE projects. But these studies have not been in vain; old reactor concepts never die – they just enter a cataleptic trance, to be resurrected later in modified form. The last OMRE gasps concerned replacing APM cladding with Zr, aluminum-clad against hydrogen pickup. Recalling an earlier bitter lesson with embrittlement from pickup of oxygen (p. 82) from sodium, it is interesting to note the good performance of Zr in the combined evils – H_2O! The next transmigration may involve the D_2O-moderated organic-cooled version.

Things often get complicated before they become simple, and while reactor control is still in its complicated stage, Freund's book serves as a valuable companion and guide. All parties concerned in its preparation are to be commended for their contribution to this neat package. For special honors we of course single out the author who, for his many hours of toil, will gain little fame and even less fortune.

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Reactor Safety Hazards Evaluation Techniques, Volumes I and II. Proceedings of the Symposium on Reactor Safety and Hazards Sponsored by the International Atomic Energy Agency and Held in Vienna 14-18 May 1962. 1088 pp., $10.00.

These are the Proceedings of the First International Symposium held to discuss reactor safety. The Proceedings are in two volumes, each consisting of 544 pages, and contain 65 papers with an additional 11 summarized in abstract form. The papers have been grouped into sections having the titles: "Review of Reactor Accidents and Incidents"; "Some Examples of National Practices and Principles"; " Safety Through Good Design and Construction"; " Safety Through Good Siting and Containment"; " Safety Through Control Devices and Instrumentation"; " Safety Through Good Administration"; "Hazards Evaluation"; and "Safety Assessment."

The title "Reactor Safety and Hazard Evaluation Techniques" and the section headings in this reviewer's opinion have been excellently chosen. The title and headings imply an important distinction between safety analysis and hazards evaluation. Hazard evaluations generally refer to the evaluation of the consequences of an already established uncontrolled radiation source while safety analysis covers a much broader problem including an assessment of the degree of safety against the establishment of an uncontrolled radiation source. The section on "Hazards Evaluation" occupies some $3\frac{1}{2}$ times as much text as any other single section. That this would be the case is not surprising in view of the significance presently being attached to the problem of site selection and in particular, the problem of evaluating the consequences of a prescribed accident in terms of dose levels. The papers covering hazards evaluations and site analysis reflect considerably more substance than papers bearing on the same subject in past meetings. The improvement in content seems to derive mainly from the availability of experimental evidence as to the behavior of a radioactive cloud in the atmosphere. Among the significant experiments reported in this field were those performed on radioactive aerosols released in a hypothetical big reactor accident. These experiments have helped to establish information on the dose accumulation in various parts of the body. In addition, there have been some important observations implying a stronger role of secondary sources. For example, in one study, reported radiation exposure from ground surface was found to be more important than that from cloud immersion.

One outstanding feature of the Proceedings is the incorporation of the discussions that followed presentation of the papers. The questions and answers contained in these discussions are very effective in conveying the different points of view existing in the various countries for performing common tasks. An encouraging note reflected in the Proceedings was that more thinking and effort is being directed towards performing safety analyses on a more quantitative basis by use of probability techniques. This is particularly observed in the section entitled "Safety Through Control Devices and Instrumentation." These papers apply probability techniques to questions of reliability, instrumentation design, and reactor safety system optimization. While none of these have advanced to the point where one could assuredly use these techniques as a formalism for conducting safety assessments, there does seem to be a basis for such models to evolve.

With symposiums being what they are, it would be a unique situation for the Proceedings to convey all available knowledge on a given field. Reactor safety is no exception; therefore, it is expected that certain subjects will be unavoidably neglected. Missing from the Proceedings was a good representation of papers synthesizing the results of current research and development in reactor