Book Review

Reactivity Coefficients in Large Fast Power Reactors, by Harry H. Hummel and David Okrent, Gordon and Breach Publishers, (1969), 376 pp., $18.40.

This monograph is one of a series on Nuclear Science and Technology, prepared under the direction of the American Nuclear Society for the Division of Technical Information of the United States Atomic Energy Commission.

Actually the scope of this book is wider than is implied by the title: of the four parts that can be distinguished only the second (Chaps. 4, 5, and 6) covers reactivity coefficients proper. The first part is a good introduction to fast reactor physics in general, and the third part (Chaps. 7, 8, and 9) goes into dynamics, stability and accident analyses. While many considerations apply to any type of fast reactor, the emphasis is definitely on sodium-cooled reactors. Other coolants are dealt with only in the fourth part (Chap. 10), consisting of just over 20 pages of this 376 page volume.

It was certainly judicious to open this work with a general introduction to fast reactor physics, particularly since not much is yet available in the way of treatises on that subject.

In Chap. 1 one finds an excellent critical discussion of the nuclear data of interest for fast reactor calculations, and particularly of the uncertainties which affect them. The authors rightly point out that accuracy in the relative fission and capture cross sections is more important than accuracy in the absolute values, and that therefore it is important that all such cross sections used in a reactor calculation be normalized to the same standard.

Chapters 2 and 3 treat the central problem in fast reactor physics: the calculation of what one could call in general "effective cross sections," i.e., self-shielded cross sections for the narrow resonances of the heavy elements (in Chap. 2), and multigroup cross sections (in Chap. 3). These two chapters are very comprehensive, and the authors discuss the various approximations and calculational methods sometimes in very great detail. One could regret, however, that they start their discussion somewhat downstream from the basic principles. A few more paragraphs on fundamentals and this treatise would have been much more self-contained. For instance I would like to have seen the justification of the flux weighting in calculating effective cross sections, which is to conserve both the eigenvalue and the reaction rates. Also a few sentences could have been devoted in Chap. 2 to the basic principle underlying the narrow resonance approximation and to the reasons why it applies to resonances of heavy elements and not to those of light elements.

The effect of heterogeneity on resonance self-shielding is treated in some detail; however it is not made clear in the text that even outside the resonance range there exists another heterogeneity effect, relative to the flux variation throughout the cell. This problem is only incidentally mentioned in Paragraphs 2-2.2. and 2-2.3. And here again one should have indicated the recipe for obtaining effective homogenized cross sections. Of course both heterogeneity effects are much less severe in power reactors--the subject of this book—than in critical assemblies.

In Chap. 3, which is otherwise excellent, a few additional sentences and equations could have explained to the readers what constitutes the various P-1 and B-1 approximations. These minor deficiencies are, however, compensated by a comprehensive list of references. Together with those references, these two chapters constitute an excellent introduction to the central problem of fast reactor physics.

The one hundred page second part covers reactivity coefficients proper i.e., the sodium-void effect, the Doppler effect, and the motion of fuel and structure. This part is very instructive and very complete. It is not limited to the calculational methods. The authors give numerous practical results and indicate how the various coefficients are affected by the reactor composition, the temperature, the geometry, etc.

The authors discuss the errors in the methods and the uncertainties arising from cross-section uncertainties, and also compare calculation with experiment. Each of these three chapters also contains reactor design considerations.

The discussion of the validity of first-order perturbation theory for calculating the sodium-void effect is not very clear. The first-order results which are presented were apparently obtained with a broad-group structure and the observed discrepancies are probably due in large part to this structure rather than to the first-order approach. The effect of the broad-group structure is briefly described in Paragraph 4-6.3. The validity of the first-order model could best be ascertained by the use of an ultra-fine group structure in (fundamental mode) perturbation calculations. The applicability of first-order perturbation theory is more than a computational convenience: it shows to what extent one can apply the principles of linearity (Δk proportional to the quantity of sodium removed) and of additivity [effect of void A + effect of void B equal to effect of void ($A + B$)].

Part three covers time constants, transient heat-transfer and reactor stability (Chap. 7), super-prompt-critical reactivity accidents (Chap. 8), and reactivity coefficients and accident analyses (Chap. 9).

The presentation of these various topics is very clear and well organized. In Chap. 7 the reader will find in particular an account of the instabilities encountered in the EBR-I MARK II core operation. Their mechanism is now well understood, and is well explained in the book. It is clearly shown that, based on this experience, fast reactors can now be designed—and demonstrated—to be stable.

In Chap. 8 one will find a good presentation of the classical Bethe-Tait method for the analysis of reactor explosions, and of the more refined and complex methods which have been developed later, which take the Doppler effect and the vapor pressure (prior to the obtainment of the energy threshold) into account. However the authors devote only two sentences to the very important problem of the thermodynamic interaction between fuel and sodium: this not being a book on fast reactor safety, the authors had to stop somewhere. But again they provide us with many numerical examples and practical design considerations. Other accidents including loss-of-coolant flow, mild reactivity excursions, and sodium voiding are dealt with in Chap. 9, with, again, many illustrative examples.

The treatment of other coolants (Chap. 10) is very succinct: about 20 pages for steam cooling, and just over 1 page for gas cooling. There obviously is room for another book on these coolants.

In conclusion I would say that this work should be required reading for practicing fast reactor physicists and nuclear engineers. They will find in it a lot of very instructive material, including, as well, calculational methods and numerous practical results which the authors have assembled. This monograph could also be used as a textbook on fast reactor reactivity coefficients and dynamics. With a few additional paragraphs here and there it could even have provided a self-contained introduction to the fundamentals of fast reactor physics.

The presentation is very clear and remarkably free of errors. I did find one on page 4: η is incorrectly defined as reactor neutrons per fission.

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About the reviewer: Fred Storrer has been engaged in fast reactor physics since 1956, first at Belgonucléaire, then at APDA, and for the last 11 years at the nuclear Centre of Cadarache, France, on behalf of Euratom. For many years he has been teaching fast reactor physics at the National Institute of Nuclear Science and Technology of the University of Paris, and also has had various teaching assignments abroad. Storrer received his schooling at the University of Ghent, Belgium, and at the California Institute of Technology. He has authored more than 30 publications, most in fast reactor physics and dynamics.