Book Reviews

Space-Time Nuclear Reactor Kinetics. By Weston M. Stacey, Jr. Academic Press, Inc., New York (1969). 186 pp. $13.

This attractive little monograph is devoted to recent theoretical developments in space-dependent reactor dynamics. It is really a collection of brief review articles, and it serves its stated purpose as a bridge "between the older texts on reactor kinetics and the new work appearing in the current technical literature."

The main objection is that the book is too brief. Each topic is introduced at a rather high level of sophistication. Nobody will mistake this book for a text; it is written for well-indoctrinated specialists.

Several of the chapters end abruptly. The author has taken the reader across a bridge and dropped him there. What next? Have we arrived at the frontier, or has the author lost interest? This is not idle wishing for the "graceful exit" of literary style. Some readers will miss the perspectives that might have been provided in closing some of the chapters, especially the chapters on variational synthesis, stochastic kinetics, and control.

Some well chosen numerical results are presented. Many other examples have been published in journals; some of these are cited in the references. The book would be better able to stand alone if more numerical examples had been reproduced (with appropriate commentaries). A larger bibliography would have been helpful, and a more comprehensive subject index should have been prepared.

For the record, the authors of Ref. 3 (pp. 3 and 149) are A. Z. Akcasu, G. S. Lellouche, and L. M. Shotkin.

With reference to p. 11: it would be proper to quote Al Henry's observation that natural modes occur in clusters of seven. It is, however, a bit of a leap to assert, without commentary, analogous properties for the eigenvalues of the finite-difference formulation represented by Eq. (1.12).

The quasistatic method of Ott and Meneley shows great promise. It deserves more than the passing reference on p. 32.

Section 2.7 is devoted to the alternating-direction implicit method. Attention should be called to the alternating-direction explicit method (Ref. 11 of Chap. 2). The latter is more straightforward and probably more efficient. As a result of Denning's work, its importance is beginning to be realized in this country.

The variational method has a strong appeal, but its virtues should not be exaggerated. The impression is given on p. 63 that there is no restriction upon the weighting functions. In fact, the weighting functions are adjoint to the expansion functions. If one wants both sets of functions to be arbitrary, then one has to forego the existence of a variational principle (a small price to pay in most practical problems).

Figure 5.1 is not a phase plane, as asserted on p. 125. It is a two-dimensional parameter space.

Computer jargon like "edit region XX" should have been stamped out by the manuscript editor. It can possibly be forgiven in the figures (Chap. 5) but not in the text (p. 133).

There is a confusing point on p. 144. The Region R "within which the linear analysis is valid" is not the same region R in which V exists (p. 142). This reader fell into a trap, and he hastily composed several indignant (and superfluous) paragraphs about what the Liapunov method can and cannot do for linear systems. Let authors and critics both be more punctilious.

If there are more words of criticism than praise in this review, it is because critical comments are easier to write. Actually, it was a pleasure to read this book. The author writes well, and he has made a valuable contribution to the literature of reactor dynamics.

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About the reviewer: David Hetrick is professor of nuclear engineering at the University of Arizona in Tucson. His current interests in teaching and research are reactor dynamics, nuclear safety, laser optics, and thermodynamics. He received his PhD in theoretical physics at UCLA in 1954. He was a reactor physicist at Atomics International for nine years, and has taught physics at Rensselaer Polytechnic Institute and San Fernando Valley State College. His textbook Dynamics of Nuclear Reactors *was published by the University of Chicago Press in 1971, and he edited the proceedings of the most recent Arizona symposium on reactor dynamics (*Dynamics of Nuclear Systems, *University of Arizona Press, 1972). Professor Hetrick assisted in the formation of the new Arizona Section of ANS.*

Mathematical Methods in Nuclear Reactor Dynamics. By Ziya Akcasu, Gerald Lellouche, and Louis Shotkin. Academic Press, Inc., New York (1971). 460 pp. $22.

The authors state in the preface to this book that they ". . . have tried not to duplicate the subject matter and approach of existing texts . . . ." The reviewer feels that the authors have taken this objective as a serious goal and as a result have produced a text which is rather orthogonal to other texts in this field. A potential pitfall in adopting such a philosophy is that the least significant aspects of the subject may be emphasized at the expense of more significant material. This reviewer believes that the authors have occasionally fallen into this trap. Of more concern, they have often not put into perspective the relative significance of the point they are developing. Another possible consequence of this objective is to dismiss more elementary concepts as trivial and to concentrate on more exotic developments. This is not bad in itself, but when it results in misleading statements concerning elementary concepts it lowers the value of the text. The reviewer finds that there is cause for concern that the student will be misled in certain elementary areas.

The authors also placed constraints on the subject matter covered. The most significant of these are the omission of space-dependent kinetics, numerical methods, and statistical methods. Consequently, the subject matter of the book is confined to analyses of the point reactor kinetics equations using analytical methods. Satisfying the objective of not duplicating other texts within these rather narrow constraints has amplified the problem of selecting appropriate material.

In the first chapter the general kinetics equations are developed. The starting point is the transport equation for neutrons and the precursor balance. Feedback equations are developed by writing equations for the variations of microscopic cross sections and atomic densities. Distribution of heat sources are discussed and the production and burnup of nuclear species. The transport-theory set of equations is cast into the diffusion approximation, the Fermi age model, and one group diffusion. The concept of adjoint flux is introduced through an example problem concerning the effect of gravitational forces on neutron distributions.

The first chapter illustrates a point referred to earlier. For example, the authors find that "if the reactor is just critical in the absence of gravity . . . , then the reactor becomes subcritical when gravity is present." Suprisingly, they do not discuss the magnitude of this effect. This is an illustration of emphasizing an obscure problem and not putting its significance into perspective.

In the second chapter, the point reactor kinetics equations are developed using the transport equations as a starting point. Adjoint functions and importance are carefully introduced and the parameters of the kinetics equations are explicitly derived. With all of the machinery developed in Chap. 2, it would seem that one would not hesitate to attack space-dependent dynamics problems. However, the authors have chosen not to proceed along this line. By not addressing space-dependent problems after developing such a strong theoretical foundation, the derivations of this chapter take on the characteristic of hunting ducks with a battleship.

In Chap. 3 the point reactor kinetic equations are solved exactly for reactivity with various power variations and for power with a step and ramp reactivity insertion. In this chapter the problem of making misleading statements about mundane (but important) concepts is evident. For example, the inhour equation is graphed in a distorted form. The fact that the graph is highly distorted and the consequences of this distortion are never mentioned. It would appear from this graph that, in general, $|\lambda_1| < \beta/l < |\lambda_2|$ and the λ_i are uniformly distributed. Other strange statements appear in Chap. 3, such as the assertion that the motivation for analyzing a step reactivity insertion into a subcritical reactor is ". . . the fact that a reactor is never free from an external neutron source due to the photoneutrons produced by the gamma field, and therefore is never truly critical," as well as "When $k_0 > 0$ but less than 1\$, then the reactor is said to be delayed-critical."

In Chap. 4 we find approximate solutions to the point reactor kinetics equations without feedback. Special attention is given to gradual reactivity changes and oscillatory reactivities. Again, the problem of emphasizing the obscure and obfuscating the obvious is evident. The phenomena of divergent power oscillations or negative reactivity bias in oscillator experiments are dealt with exhaustively. On the other hand, it is asserted that in the one delayed-neutron group model ". . . the phase angle is always negative, equal to -45° lag at the break frequencies . . ." when, of course, there is always a greater phase lag than -45° in this model at the break frequencies. The authors also state, without qualification, that "the pile oscillator technique . . . is one of the most precise methods for measuring β/l" when, in fact, the pile oscillator is unusable in fast reactors.

Chapter 5, on feedback, repeats the pattern of earlier chapters. In keeping with the objective of not duplicating other work, problems associated with the response to large reactivity insertions are not covered. Feedback terms are derived quite generally but specialized to point reactor problems for both temperature and xenon. Periodic reactivity insertions are revisited, this time with feedback. For some reason, Chap. 5 has no exercise problems whereas all other chapters do.

Chapter 6 is on linear stability analysis. In a linear stability analysis for a point reactor with xenon and temperature feedback we learn that "a time delay in a single-temperature feedback can have a destabilizing influence on a reactor dominated by xenon feedback. The longer the time delay, the more unstable the system." The reviewer finds this to be the peak of irrelevant problems with irrelevant conclusions. In the first place, space-independent xenon stability is relatively unimportant, but the effect of thermal time constants of the same order as xenon time constants is probably the most irrelevant stability problem in the field of reactor dynamics.

Chapter 7 is a long (133 pages) and academic chapter on nonlinear stability analysis. Concepts of stability such as "asymptotic stability in the large" are defined and elaborated. General criteria for boundedness of solutions with arbitrary feedback functionals and specializations to linear feedback are presented. Lyapunov's second method is introduced and various Lyapunov functions based on the Lurie-Letov function are exercised. Other stability criteria such as the Lefschetz and Popov criteria are also developed. Finally, the concept of finite escape time in reactor kinetics is developed and applied to simple reactor models.

The authors have done a real service by bringing together much of the literature in nonlinear reactor dynamics which has previously been distributed in various journals. For example, they introduce a proof of a theorem by Popov which is not presently available in the English-language literature. Unfortunately, the state-of-the-art of nonlinear analytical methods in nuclear reactor stability has not yet been developed to the point of significant application to real systems. The models are still too simplified to adequately describe the detailed characteristics of engineering systems. However, Chap. 7 does an excellent job of covering the fundamentals of this difficult subject.

This review may seem rather negative, but for the specialist who would like to have thorough mathematical derivations of space-independent kinetics and who would like to have reference to a collection of problems not found in other texts, I recommend the book. I would also tend to recommend the book to some students who have already completed a course in nuclear reactor dynamics of the more traditional variety. However, I feel that its tendency to emphasize the off-beat areas of reactor dynamics at the expense of the more commonplace makes it a very poor pedagogical instrument for the uninitiated.

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About the reviewer: Bob Albrecht is a professor of nuclear engineering at the University of Washington. He has been teaching nuclear reactor dynamics for the past 11 years and doing research related to stochastic fluctuations in nuclear reactor observables. Dr. Albrecht obtained his PhD at the University of Michigan in 1961 and received the Mark Mills award in that year for a paper based on his dissertation. During 1967-1968 he spent a year doing research at Kernforschungszentrum Karlsruhe.

Optimal Control of Nuclear Reactors. By Ronald R. Mohler and C. N. Shen. Academic Press, Inc., New York (1971). 320 pp.

This book is based on and primarily features specific research by the authors in the control of nuclear powered rocket engines. Its first two chapters give a condensed survey of reactor kinetics and optimal control fundamentals to refresh the memories of those already knowledgeable in these areas. Readers not so qualifying are likely to be left "standing at the starting gate." The last chapter gives selected optimal control topics from other sources. Remaining is the main body of the text which is devoted to analytical and numerical applications in nuclear rocket control.

Typical subjects treated from the standpoint of their utilization in optimal control are the Euler-Lagrange equation, the Bellman-Hamilton-Jacobi equation, the maximum principle, and linear programming. Typical problems solved utilizing these methods are reactor startups with minimum time or minimum propellant consumption. In these problems typical imposed constraints would be not exceeding control capabilities or not exceeding limits on thermal stresses.

A more descriptive book title might be "Optimal Control Theory and Its Application to Nuclear Rockets." While the needs of rocketry are quite unique and specialized, nevertheless many general aspects of control theory and applications are clearly presented. In this respect the two control chapters written by Shen are outstanding. They overlap and repeat some material in Mohler's chapters. But perhaps Shen goes too far in lucidity when a step by step numerical conversion is given to show 1 g/cm^3 of water contains 6.94 lb/ft^3 of hydrogen.

The chapters by Mohler also are largely derivations of reactivity control methods of achieving a minimum cost (ex., fuel usage) functional. A variety of methods is treated in detail—even down to pages of FORTRAN statements of a quasi-linear programming algorithm. Computer utilization in achieving results is a necessity and here this book is quite up to date.

Specific examples of results—graphs of power, reactivity etc. during rocket startups—are frequent. These remind one of the practical utility of the methods presented. The reader is therefore intermittently brought back from the abstract world of the calculus of variations and into the world of concrete practical reality. Also assisting in this respect are discussions of the physical processes involved and of intuitive rationale for results obtained.

There is no special glossary, though Shen's chapters define some terms as they are used. A policy for defining control and reactor jargon or for defining lesser used mathematical terms might exist in a school text, but would not be required in a book of this nature, aimed at the experienced specialized researcher. An example of the lack of a policy is defining "bang-bang" control on the last pages, after it has been repeatedly mentioned throughout the book.

It is not to be expected from the book title that one would find an excellent treatment of heat transfer and thermal stresses spanning a third of a chapter, and also lucid extensive discussions of the neutron kinetics equations at various places. But with these topics adequately treated in many texts, it would have been better to devote their space to control theory—such as expanding the variety of optimum control topics in the last chapter.

The authors intended this book for systems theoreticians, nuclear engineers with a strong background in control theory, and graduate students specializing in this field. It will well serve this select group, who, moreover, should no doubt find the bibliographies listing original papers well worth pursuing.

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About the Reviewer: Joseph A. Thie is an independent consultant to the reactor industry. Prior to 1960 he pioneered in boiling water reactor development at Argonne National Laboratory. Subsequently he has been a consultant for utilities and manufacturers in the fields of reactor design, experimentation operation, and safety. Among his publications are many papers treating random fluctuations, including his book Reactor Noise. Other books which he has either authored or coauthored are Heavy Water Exponential Experiments Using ThO_2 and UO_2, Nuclear Reactor Instrumentation Systems, and The Technology of Nuclear Reactor Safety.

Fast Reactor Safety. By John Graham. Academic Press, Inc., New York (Dec. 1971). 367 pp. $18.00.

The author's preface states that this book is intended "as a university text for reactor safety applied to fast reactors in general and applied to liquid metal-cooled fast breeders (LMFBRs) in particular." The author also intends the book "as a text for graduates and undergraduates in nuclear engineering who are attending courses in reactor safety." Within this context, the book approaches its objective, albeit with mixed success and a rather different emphasis than I might choose. The publisher's statement on the book jacket that "this volume presents the latest information on the whole field of safety as applied to the fast breeder reactor power system," however, is not valid. Nor is the jacket statement that the book will be of "great interest to . . . practicing nuclear engineers and power engineers who want to acquire a working knowledge of nuclear safety." Finally, by way of introduction, the book does not, as stated in the forward by J. J. Taylor, "examine, as quantitatively as our present technological capability permits, the specific features of safety of the fast system."