Book Reviews

Dynamics of Nuclear Systems. David L. Hetrick, Ed., University of Arizona Press (1972). 606 pp. $14.50.

Dynamics of Nuclear Systems, a volume of papers contributed to the University of Arizona's Symposium on the Dynamics of Nuclear Systems and edited by David Hetrick, is first-class. Responsible physicists, mathematicians, and engineers must read or browse through it to discover the state of our knowledge of reactor dynamics in 1970; the ensuing three years have not produced great changes.

Not all of the papers are dense with equations. After completing T. J. Thompson's survey of crucial problems facing the AEC's program, in "The Interaction of Reactor Dynamics with Nuclear Safety," the reader can turn to C. N. Kelber and A. M. Judd's "Research Program for LMFBR Safety" and G. L. Gyorey's "Industrial Requirements in Reactor Transient Analysis." These three papers, rich in ideas and points of view, are also equation-free.

I would suggest that the mathematical engineer turn next to a pair of papers which summarize our knowledge of computational methods. These are A. F. Henry's general review of computational methods and K. F. Hansen's review of finite difference schemes. Here, as elsewhere in the volume, the competition between modal, nodal, and differencing methods is apparent. A strong case is made for synthesis techniques (the "finite elements" of yore, classified here as modal) in papers introduced by W. M. Stacey, Jr., J. D. Yasinsky, and M. Becker. There are other worthy papers on calculations and models, but one in particular entitled "Some Pitfalls in Reactor Kinetics Calculations," will delight the reader. Its authors, G. A. Mortensen and G. E. Putnam, discuss four pitfalls they encountered in constructing relatively simple models, using the results of more complex calculations. Their case histories are enlightening; they emphasize again the need for care and physical insight along with computational celerity.

The volume holds several papers devoted to the thorough study of simple models in which analytical techniques are effective. These papers are markedly fewer in number than those presented at the previous Arizona meeting of 1965. In 1970 they were not only in the minority, but seemed to constitute a separate field, disjoint from the majority. I, as somewhat of an outsider at the meeting, found this particularly disturbing. Many experts at computation regard the analytical work as "irrelevant" and rarely weave its results into their presentations. Yet how is one convinced that the results of a complex calculation are correct? Is every such paper accompanied by a rigorous analysis of error? The gap between our computational ability and analytic insight is great. It should not be tolerated by a self-respecting technology.

The analytical papers include one by H. Smets on finite escape times, D. L. Hetrick's interesting survey of the nonlinear stability of the point-reactor model, and J. Canosa's clear and thorough discussion of a classic problem in nonlinear space-dependent kinetics. W. E. Kastenberg and R. Ziskind discuss the important new approach to stability, based on comparison theorems, that has marked much of Kastenberg's recent work. There are also papers on "pulses and waves," a rather classical subject in the linear theory. My review of the subject concerned material that has since been presented elsewhere; thus, no manuscript exists. A part of the talk, entitled "Who's Afraid of Academician I. N. Vekua?," described how one could avoid the elegant but complex mathematics of the theory of quasi-analytic functions (Vekua) in the transport theory of pulses and waves. In just about every case, old-fashioned analytic continuation does the trick.

Many scientists have grumbled at the paucity of clean, "hard," experimental data describing reactor kinetics in the presence of feedback. One has nothing like the array of decay constants which challenge the theoretician in the feedback-free case. Thus, it is a pleasure to find G. S. Lellouche and L. M. Shotkin's "Guide to the Experimental Reactor-Excursion Literature" in this volume, along with M. D. Green and E. P. Gyftopoulos' discussion of scaling and correlations during power excursions. D. C. Wade and R. A. Rydin's experiments on flux "tilting" and eigenvalue separation are based on the linear theory, but they are nonetheless intriguing. All of these theoretical and experimental studies constitute perhaps half of the papers appearing in the volume. Many other excellent ones await the reader who has perhaps been lured by these samples.

The late T. J. Thompson, then a member of the U.S. Atomic Energy Commission, proposed a theme for the Symposium: "*. . . solve real problems and solve them right.*" In his opening address, which heads the volume, Thompson elaborated upon his slogan. Briefly, "real" problems connected with the engineering aspects of nuclear safety are those analyzed by the equations of reactor kinetics, augmented by a wealth of feedback mechanisms; all are based on "real" configurations of fuel and coolant.

There can be no argument about the importance of the class of problems which Thompson discussed. Nor can one deny the extraordinary influence that such pronouncements have on the conduct of research in universities and laboratories. For that reason I wish Thompson had used a word other than "real" in his slogan, since "real" encodes so much. For example, it is usually opposed to "academic." It prefers the larger set of equations, the more elaborate geometry. It urges one on to three-dimensional codes before two-dimensional systems are well understood. And, it evokes the counter argument, which I abstract from Weinberg and Wigner's famous preface, that substitution of ". . . a code for a theory, . . . a . . . display of many curves for a detailed *physical* understanding of the system . . . " is deplorable. Of course, we are all aware of these dangers and steer between the extremes. And yet . . .

It is appropriate that the Proceedings have been dedicated to the memory of Theos J. Thompson. Tommy was very much at the center of things in Tucson. We were all proud of him, proud that "one of us" would sit with the Commission and fight the good fight for superb science and technology. How much of a fight lay ahead came to me with a simple remark. After Thompson finished his address outlining in detail specific investigations needed in the dynamics and safety program, a young and talented colleague turned to me and said, "Those are precisely the lines of research I proposed to the DRD. They replied that they weren't interested."

Noel Corngold

California Institute of Technology
Pasadena, California 91109

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About the Reviewer: Noel Corngold has been professor of applied science at the California Institute of Technology since 1966, following 15 productive years at the Brookhaven National Laboratory. Dr. Corngold's graduate studies were at Harvard. His research interests have been in reactor and statistical physics, particularly in the theory of neutron scattering and transport.

Application of Invariant Imbedding to Reactor Physics. By Akinao Shimizu and Katsutada Aoki. Academic Press, Inc., New York (1972). 184 pp. $13.50.

Application of Invariant Imbedding to Reactor Physics consists of two parts. This little monograph treats the application of invariant imbedding theory to shielding calcu- two-dimensional systems (part B).

Part A begins with a brief recapitulation of photon cross sections and a quick review of the classical methods used for the solution of gamma-ray reflection and transmission problems. After a general discussion of the differences between the classical Boltzmann approach and the invariant imbedding approach to radiation transfer, the basic invariant imbedding equations are derived in Chap. 2 and then solved for some model problems in Chap. 3. The whole of Chap. 4 is devoted to the numerical method of solution which is then illustrated in Chap. 5 by numerous examples, including the reflection of gamma rays from various substances, dose transmissions, and buildup factors. The numerical material is here extensively confronted with Monte Carlo and moments calculations, as well as with experimental evidence.

Part A is an excellent introduction to the invariant imbedding theory for those who expect a clear physical motivation of the derived equations, not stuffed with proofs of existence and uniqueness, yet presenting a sharp distinction between the Boltzmann and invariant imbedding approaches. Simultaneously, the presented material is very convincing concerning the usefulness of the theory in shielding calculations, although the authors do not make a secret out of the fact that an extension of the theory to two-dimensional problems is an unsolved (or unsolvable?) problem today. The question is the reviewer's and is best illustrated by the fact that almost 15 years after the formulation of the theory by Bellman and Kalaba, invariant imbedding equations have only been generalized to spherical and infinite cylindrical geometries. But do we have to follow this way? The answer to that question is given by the authors in part B of their book.

Part B begins with a short review of the classical approach to reactor criticality problems which leads to multigroup diffusion equations that have to be solved in the reactor core (Chap. 6). Although the invariant imbedding equations for plane geometry can be supplemented with terms describing the fission process, they have not been further analyzed. Instead, the authors pass directly to the formulation of their own modification of invariant imbedding theory, the response matrix theory (Chap. 7). The latter uses the same concepts as invariant imbedding, such as partial currents and reflection and transmission matrices, but it does not use any functional relations between the response functions. Therefore, the response matrix theory can be extended to geometries where those relations do not hold any more or, even if they could be established, from which it would be too involved to construct invariant imbedding equations in a similar manner as Bellman did for plane geometry.

Application of the response matrix method to one-dimensional systems is given in Chap. 7. It is further developed for two-dimensional systems in Chap. 8 where the monograph culminates (and ends rather abruptly) in the description of the author's two-dimensional diffusion theory code, MERMAID. The numerical examples illustrate the potentialities of the response matrix method in comparison with the finite difference method. However, the material chosen does not go far beyond that published by the authors up to 1965, namely, a homogeneous bare reactor, a reactor with reflector, and the Toshiba Training Reactor. In the light of the present demands imposed on any numerical method which should compete with the finite difference technique, those examples are, however, not convincing. How would the method describe a large power reactor core, like that of a large BWR? Will the linear correction for the interface current distributions still be sufficient?

The monograph would be more up to date if examples of a typical PWR and a BWR were also included. Perhaps the method would then become a little less attractive, but the results would be more valuable. For instance, the first two examples refer to quadratic nodes in quadratic homogeneous cores. Experience shows that such systems are extremely favorable for nodal and macromesh methods. The problem starts with larger, rather loosely coupled BWR cores with large variation of the diffusion constant (due to void distribution) between neighboring nodes. The two other examples (pp. 8.5.3 and 8.6.1) do not resolve that problem, as they refer to relatively small, rather strongly coupled cores. Besides, in the last example no reference is made to other numerical methods, say a finite difference calculation with homogenized node data. Such a comparison would be very instructive and possibly throw additional glamor over the response matrix method. For completeness, the method should also be compared with other "fast" calculating models. In two-dimensions the nearest seems to be the finite element method with square nodes. In conclusion, the reviewer's intention would be, at this place, to warn the reader against a too optimistic generalization of the numerical examples of part B to problems encountered in power reactors today.

Thus we come to the main weakness of the monograph. Although it was edited in 1972, the most recent publications quoted by the authors date from 1968 in part A and from 1966 in part B. This rather large time gap does not qualify the book as a review of the state of the art, which, judging from the editing date, one would expect to have been updated to at least 1970. On p. 102, when referring to flux