About the Reviewer: We, and I am sure our readers, welcome Herbert Parker to these columns again as the reviewer of another book on radiation protection. Mr. Parker, trained as a physicist in England (MSc., F. Inst. Phy.), began his career in nuclear energy at the Metallurgical Laboratory, University of Chicago, in 1942 when the Health Physics profession was founded. He subsequently managed the Hanford Laboratories, Richland, Washington for nine years and is now a consultant to the Director of the Pacific Northwest Laboratories of the Battelle Memorial Institute.

Economic Strategy for Developing Breeder Reactors. By Paul MacAvoy, The MIT Press (1969). 199 pp. $10.00.

This is an important book. Briefly summarized, the study relies on three major analytic tools. First, MacAvoy undertakes a probability analysis of R&D costs and performance goals for the Liquid Metal Fast Breeder Reactor (LMFBR), the Gas Cooled Fast Breeder Reactor (GCFBR), and a dual program. Second, he develops a nationwide econometric model using Edison Electric Institute nine-region data to project both total electricity consumption and the nuclear share of that consumption. Third, production functions as well as associated electricity production costs are estimated. Public benefits are expressed as the discounted increase in consumer's research resulting from the increased electricity consumption, and the public cost is taken as the discounted R&D costs.

In Chap. 4, the author makes a cogent argument for a two-pronged attack on breeder development. He concludes that (a) future economic benefits will probably exceed development costs for either a gas-cooled or liquid-metal-cooled program, (b) the net present value of benefits for GCFR development appear to be higher than those for an LMFBR program, and (c) developing both types is superior to developing either alone. One important point associated with this latter conclusion is the belief that a two part development program will result in greater industry competition and lower future power costs. This is a conclusion affecting billions of dollars of public funds, and merits substantial consideration.

The assumptions and economic data on which the above conclusions are based appear to be reasonable and consistent with those used in other independent studies of the U.S. Civilian Power Program; however, the total electrical capacity forecast to the end of the study period (2005 A.D.) may be overoptimistic. The author's derived figure of 2 370 000 MW(e) added during the period 1985 through 2004 corresponds to annual growth rates ranging from 7.5 to 8.3% which are considerably higher than the 5.5% growth rate projected by the Federal Power Commission and the USAEC for this same period. The author's forecast procedure, described in detail in Appendix C, does not allow for saturation of some of the future markets for electricity such as home heating, for example. With a lower capacity demand, the net present value of benefits would be less than shown; however, the overall conclusions would probably remain unchanged.

Three other types of criticism may also be levied against the book. First, it has some proofing errors. Second, certain Gordian knots in economic theory are cleaved by simplicity in a non-convincing fashion. Third, the discussions of the technical aspects of the fission reaction are inaccurate. In general, these criticisms will not interfere with the reader interested in the analytic approach described and the resulting conclusions drawn. However, the serious student of methodology will find these deficiencies somewhat frustrating, if not misleading. Fortunately, the proofing errors are evident with some thought on the reader's part and the technical discussions are not relevant to the main theme of the book.

More seriously, the author can be faulted for his Cyclopean view of certain contentious issues in economics. Specifically, consumers' surplus and single-equation demand estimation are both highly controversial. MacAvoy does his readers an injustice by not noting the logical limitations of his techniques as well as part of the voluminous literature centered upon them.

The discussion of probability and its utilization in the analysis is, in general, quite impressive. It sets a standard for other resource economists for the next few years. A minor defect, however, exists in the equal probabilities assigned to low costs, design costs, and high costs in Chap. 2. The data reported in Appendix A are a strong argument for assigning high costs a greater probability than low costs. Net benefits would be somewhat lower, for example, if $P(L) = 0.2$ and $P(D) = P(H) = 0.4$.

An error of probably minor importance appears in the first chapter. The figures there (as well as elsewhere in the book) show marginal cost as rising or constant. It seems more likely that marginal cost decreases over a significant range, and that this is one of the complexities of public policy in determining the degree of competition to encourage.

Finally, the paragraph describing benefit-cost analysis on page 3 would be more relevant to the book if the phrase "general environmental benefits" were deleted. Heat discharge, transmission lines, radioactive emissions, and explosion possibility are omitted from any consideration in breeder development. Analogously, the effects of strip mining, combustion by-products, and oil leakage are environmental effects of other steam-electric processes which are not considered in estimating the nuclear share. While the study is most comprehensive as it stands, it should be realized that an important component of benefits and costs was omitted.

Despite the foregoing comments, these reviewers feel that the author has done an excellent job of showing how one applies a benefit-cost analysis to alternative fast breeder strategies. The book is well written and adequately documented. The points raised in this review do not substantially detract from the objectives of the book nor from the conclusions reached.

James A. Lane
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January 5, 1970

About the Reviewers: Jim Lane and Duane Chapman are presently associated with the group at Oak Ridge National Laboratory that is making a study of the feasibility of agro-industrial complexes centered around nuclear reactors in the Middle East. The former is now the Director of the Group. He has held many responsible positions, at both ORNL and AEC Headquarters, concerned with future planning for nuclear energy, a career he began at the Metallurgical Laboratory, University of Chicago, in 1942 following graduate studies in chemical engineering at Worcester Polytechnic Institute.

Dr. Chapman completed his graduate studies in resource economics at the University of California, Berkeley, in 1969 and has, in the past, served the Social Security Administration and the National Park Service as an economist. Presently he is also an assistant professor of economics at the University of Tennessee.

The Art of Computer Programming, Volume II. By Donald E. Knuth. Addison-Wesley Publishing Company, Reading, Mass. (1969). 624 pp. $18.50.

This book, subtitled "Seminumerical Algorithms," is the second of a proposed series of seven books on *The Art of Computer Programming.* The author indicates in the preface that he has intended to cover the topic of the interrelation of numerical mathematics and computer science. The topics treated are well balanced between rigorous mathematical proofs, and the limitations placed on solving these mathematical problems due to the characteristics of a computer. The material in this book is considerably more mathematically oriented than was Volume I, which has been previously reviewed by W. J. Worlton [*Nucl. Sci. Eng.*, 34, 198 (1968)]. This series of books is perhaps the most ambitious undertaking in this field to date.

The first of the two chapters deals with random numbers which, as the author points out, is a subject often not fully understood by many of the people using random numbers. Knuth has skillfully blended the many aspects of generating and using random numbers into an easily readable and rigorous presentation. The fact that much of the material has appeared previously only in papers exploring specific aspects of the subject should make this book a valuable reference for anyone using random numbers. Numerous techniques for random number generation are explored along with a thorough study of the adequacy of each technique. Also included in this chapter is a collection of techniques for performing tests to determine the randomness of a given set of variables.

The second chapter, entitled "Arithmetic," is a comprehensive study of how the various arithmetic operations are accomplished using a computer. In order to put this chapter into perspective, Knuth begins with a most fascinating history of number systems and works his way through such topics as floating-point arithmetic, multiple-precision calculations, radix conversion, rational arithmetic, polynomial arithmetic, and manipulation of power series. All of these subjects are covered in considerable detail with special attention given to the retention of as much accuracy as possible while carrying out these arithmetic operations.

The subjects discussed are often illustrated by a short computer program written in a language which the author has dubbed MIX. While this language is not the same as one would encounter on any computer now in existence, the transition to an existing computer should be relatively simple. Consequently, any of the given techniques could easily be implemented on most computers with a minimum of effort.

The people who will benefit most from this book are those who are interested in computer design, in compiler systems, and in number and probability theory. This is not to indicate that the casual user of a computer cannot obtain much from the book. The book is written in such a manner as to serve as an excellent text book for computer science studies. Particularly welcome are the 650 exercises which have been graded as to their degree of difficulty. Most of these exercises have detailed answers given which comprise approximately one-fifth of the 624 pages in the book.

The high degree of readability, which has been accomplished by the use of a sense of humor not often found in such technical works, along with the excellent technical content, should insure that this work will find wide acceptance and usage.

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January 13, 1970

About the Reviewer: Elliott Whitesides is Head of the Nuclear Engineering Section of the Oak Ridge Computing Technology Center where he has been located since 1960. He was trained as a Nuclear Engineer at the North Carolina State University. Mr. Whitesides' principal interest is the solution of neutron transport problems arising in nuclear criticality safety analyses to which he has made significant contributions in the application of Monte Carlo methods.

Formal Languages and their Relation to Automata. John E. Hopcroft and Jeffrey D. Ullman, Addison-Wesley, Reading, Massachusetts (1969). 242 pp, $11.95.

This work is an extremely valuable addition to the present short supply of good textbooks available in the realm of the computer sciences. On the whole, the material is presented with extreme clarity. Any student at the senior or graduate level in mathematics should have no trouble following the subject area of this book.

The subject of formal language theory or automata theory, can be made to be quite a complex one, and indeed, a large portion of the literature requires careful concentration on the part of the reader to grasp the more significant facts. It would probably have been much easier for the authors to continue this pattern than to present the material in the way that they actually did.

Bearing this in mind, there are at least four factors which contribute to the clarity of the book and which the reviewer feels are worth mentioning.

1. The proofs of the theorems do not go to an unnecessarily deep level. Acceptance of the proof of a theorem is generally thought to be in the mind of the reader. If he can be made to accept a proof with a minimum of complexity, then this is probably the best possible statement of the proof. The authors have demonstrated a remarkable proficiency to state their proofs in this manner.

2. The notation used by the authors is simple and consistent. The amount of notation is also held to a minimum, further enhancing the clarity.

3. For almost every concept which may be difficult for the reader to grasp, the authors supply an example which usually elucidates the concept.

4. Only the most significant results in the field of formal languages and automata theory are presented, contributing to the conciseness of the work. On the other hand, the work is, to a very satisfactory degree, complete. In this sense, the reader is brought to the threshold of the present-day state-of-the-art.

Formal Languages and their Relation to Automata is worthwhile reading and is highly recommended for the