Book Reviews

Thermal Analysis of Liquid-Metal Fast Breeder Reactors. By Y. S. Tang, R. D. Coffield, and R. A. Markley, Jr. American Nuclear Society, La Grange Park, Illinois (1978). 395 pp. $39.65.

Fast breeder reactors cooled by liquid metals are an established feature of the nuclear scene. Indeed, one such, the NaK-cooled Dounreay Fast Reactor, has come and gone after 18 yr of successful operation. What is surprising is not that a book should now appear on the thermal analysis of such reactors, but rather that none has appeared earlier. The authors of this monograph are to be commended on so comprehensively filling the gap.

The book is one of a continuing series published by the American Nuclear Society with the declared aim of bringing to print "the most useful material in the more active areas of nuclear science and technology development." It is directed largely at scientists and engineers concerned with nuclear energy applications, but it is intended also to be of value to lecturers and students in this field. The authors in their preface state the book's purposes to be to

1. create a general awareness of the technical tools available and the analyses performed for the thermal design of liquid-metal fast breeder reactors (LMFBRs)
2. summarize the current status in the thermal and hydraulic areas
3. prepare practicing engineers and students for the future demand of a work force in the field of breeder reactors.

The broad sweep of the third objective might require somewhat more than this book for its realization, but the first two purposes will certainly be achieved.

There are seven chapters, two appendixes, and a daunting ten pages of nomenclature. The first chapter gives a general description of LMFBRs, including economic incentives in terms of uranium requirements (in the U.S.), alternative design concepts, and the leading parameters of the Fast Flux Test Facility and the Clinch River Breeder Reactor projects.

More detailed descriptions of reactor configurations are given in Chap. 2, "Reactor Configurations and Operating Conditions." The bulk of the chapter, however, is devoted to core components: fuel, radial blanket and control assemblies, shielding, and core restraint. Parameters of the fuel assembly and of fuel and radial blanket pins are tabulated for French, German, Russian, U.K., and U.S. designs.

Chapter 3, "Thermal Design Criteria and Analysis Methods," presents general design requirements in terms of ASME Codes and Research and Development Technology (RDT) Standards, together with a discussion of structural and thermal design limits for fuel blanket and control rod components and vessel internals. This is followed by an account of various approaches to hot-channel and hot-spot analysis, together with a catalog of the systematic and random uncertainties to be considered.

Chapter 4, "Reactor Hydrodynamics," describes coolant flow distribution problems in reactor vessel inlet and outlet plena and fuel assemblies at normal and very low flow conditions. It covers also the phenomena of turbulent mixing, cavitation, flow-induced vibration, and fluid hammer as they are encountered in LMFBRs.

Chapter 5, "Steady-State Heat Transfer," concentrates strongly on fuel assembly considerations, rod bundle heat transfer correlations, subchannel analysis, cladding and fuel temperature distributions, intersubassembly heat transfer, decay heat removal, etc., and refers quite briefly to thermal analysis of core support structures and vessel internals.

Chapter 6, "Transient Reactor Heat Transfer," deals first with transient heat generation excited by reactivity sources and feedbacks and then examines the thermal effects on fuel and coolant of transients resulting from routine operation through to an extreme hypothetical accident. Consideration is also given to the thermal response of structural components undergoing sudden changes in surface temperature due to these transients. However, what is not spelled out loud and clear is that the combination of high surface heat transfer coefficients and the high coefficient of thermal expansion of stainless steel produces very high stress levels that, under quite modest cyclic temperature changes, could lead to component failure.

Chapter 7, "Heat Exchangers in LMFBRs," although prefaced by the comment that the intermediate heat exchangers (IHXs) and steam generators play a vital role in the successful operation of a commercial LMFBR plant, deals with the problems of IHX design all too briefly. Waterside heat transfer, dryout, and the operational stability of once-through steam generators are, however, well covered. Surprisingly, a short section covering capital cost optimization of the steam plant is included. The casual reader should be wary of drawing too elementary a conclusion from the numbers presented, since a true optimization on the basis of cost per kilowatt-hour sent out involves a much larger number of reactor and steam plant parameters as well as fuel costs, interest rates, and availability indexes.

Brief but useful descriptions of the capabilities of some two dozen thermal-hydraulics codes are presented in an appendix.

The book is in no sense a text book. There are no worked examples or specimen problems. It touches on virtually all the topics relevant to thermal analysis of LMFBRs without giving an in-depth treatment of any of them. Each chapter offers a copious list of references to which the reader must have recourse if he wishes to develop a full understanding of the methods and procedures outlined. Thus, both in style and

content, it is encyclopedic in character and will serve very well as a standard work of reference.

The style of treatment differs considerably from topic to topic, varying from the purely qualitative to detailed analysis. Numerous recommendations are made relating to correlations, codes, or calculational methods. While these in general will be found very useful, the reader should be circumspect in his acceptance of some of them. For example, there can be no universal correlation for pressure drop across pin bundle support grids. The organization of the topics is somewhat haphazard, but perhaps this is of little consequence in a work of reference. On the other hand, it would surely be better to deal with analysis of fuel elements under nominal conditions before embarking on a treatment of the uncertainties. Similarly, the discussion of flow orificing in Chap. 2 could well be omitted, given the more extensive treatment in Chap. 4, and the latter should be more closely linked to the description of radial power variation. As another example, subchannel analysis is referred to several times in the early chapters before it is fully explained on p. 206. These are minor irritations that emerge on reading the book from end to end, but are not likely to trouble the user dipping into it for information on particular topics. Overall, it will be a valuable addition to the library of people working in the field of thermal analysis of fast reactors, particularly those who already possess a good background in hydrodynamics and heat transfer.

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About the Reviewers: Gerald McAreavey holds an honors degree from London University and a postgraduate diploma from Birmingham University. He served for several years in the combustion side of the gas turbine industry in charge of a fluid flow laboratory; during this period, his main interests were flow visualization techniques and experimental studies of wall jets and turbulent jet mixing. Since 1958, he has been with the United Kingdom Atomic Energy Authority (UKAEA), involved in safety problems and the thermal-hydraulic analysis of fuel elements for both gas-cooled reactors and LMFBRs. John B. Love graduated with honors in mechanical engineering at Liverpool University in 1953. He then joined the gas turbine industry and worked for some six years on the development of centrifugal and axial flow compressors for both aircraft and industrial applications. In 1961, he joined the UKAEA. Since then, he has been involved in a wide range of work connected with rotating machinery, heat exchangers, and steam plant.

Energy Conversion Engineering. By Richard C. Bailie. Addison-Wesley Publishing Co., Inc., Reading, Massachusetts (1978). 537 pp. $19.50.

Within the current half-decade of energy anxiety in the U.S., many fine publications have made available large volumes of facts relating to the growth of energy demands and the potentiality of various supplementary energy sources. Those who have attempted to organize new college-level courses, however, have found that the recent "energy and environment" textbooks deal largely with (a) public information topics or (b) highly specific design calculations. In particular, suitable textbooks for basic instruction of upper division college students of engineering and science have not always been available. Some instructors have found it necessary to prepare their own textbooks for such upper division courses.

Energy Conversion Engineering is a thorough, carefully organized presentation of the principles, physical laws, and operational constraints that govern the performance and useful contributions of the many energy systems currently under study and application. Utilizing the fundamental *Laws of Thermodynamics*, as introduced in basic physics studies, it develops clear, connected, and quantitative methods of examination for all energy systems, with distinct conclusions that clarify some of the limitations of the many proposed "energy alternatives."

Energy Conversion Engineering has been designed to serve as a textbook for senior students in engineering and the physical sciences. It differs sharply from the "state-of-the-art reviews and data source books" on energy conversions. Following a concise, pleasantly readable review of the concurrent growth of the "Industrial Age" and the "energy age"–starting with Watt's perfection of the modern steam engine in 1765–the book then expands the relevant principles and methods from (a) Engineering Thermodynamics, (b) Chemical Thermodynamics and Equilibrium, (c) Fossil Fuel Combustion, (d) Coal Gasification and Liquefaction, (e) Nuclear Energy, (f) Solar Energy, and (g) Environmental Protection Systems. All discussions are generously and clearly illustrated with appropriate schematic diagrams, flow charts, sample calculations, significant graphs, extensive comparisons, and definite conclusions.

Perhaps the outstanding feature of the textbook is its strict adherence to the rules of procedure outlined in an early chapter. The continuity of the treatment of many diverse subjects is impressive, the methods of analysis recommended for solar systems and coal conversion being adaptations of the procedures for the evaluation of steam turbines and internal combusion engines. The assumptions and rules of interpretation are carefully established in the chapter on Engineering Thermodynamics. It will be found that these are followed consistently throughout the book.

While the book is planned for upper division college classes, guided by an experienced instructor, it is entirely plausible that it could serve for "self-instruction" by an interested and diligent student. The textbook contains an abundance of fully detailed "illustrative solutions" to typical problems. The reviewer is certain that very few textbooks equal *Energy Conversion Engineering* in this respect. Solved examples are used throughout the entire text–to emphasize the applications and interpretations in the respective cases. In fact, one could claim, justifiably, that this is a "problem-solving" manual in engineering thermodynamics. However, that would not give proper credit to the many fine verbal discussions, historical resumes, and thoughtful conclusions found throughout the presentation.

The completeness and accuracy of the quantitative and technical illustrations have already been emphasized. It should also be noted that the treatment of historical, factual, and descriptive information is equally clear, concise, and complete. For the *nonmathematical reader*, the description of energy systems, the remarks on operating conditions, and the conclusions to be inferred from the calculations form a narrative that is largely independent of the mathematical details. One finds that omission of the carefully designed illustrative examples detracts very little from the instructional quality of