Heat Transfer and Fluid Flow in Nuclear Systems

Editor Henri Fenech

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Reviewer G. B. Melese-d'Hospital

This book, which is edited by Professor Henri Fenech of the University of California (Santa Barbara), has six chapters, some divided into several subchapters, with 14 international contributors, each one being an expert in his own field. Two Frenchmen, M. Robin and R. Semeria, have contributed to liquid-metal fast breeder reactor (LMFBR) thermal hydraulics, while two German authors, E. Achenbach and M. Dalle Donne deal, respectively, with helium-cooled pebble bed reactors and fast reactors. In his introduction, Dr. Fenech indicates that this book should prove useful to engineers, scientists, and graduate students (problems are provided) with the equivalent of a one-year graduate course in thermal hydraulics. Some chapters, such as the chapter on sodium boiling dynamics, may be overspecialized for students.

An introductory chapter written by Professor Fenech first deals with safety requirements for the thermal design of nuclear systems, which might prove to be useful to nonnuclear specialists. General discussion of fuels and cladding materials and of fuel element design serves as a useful introduction to the succeeding chapters, which focus on only one specific coolant type, pressurized water, boiling water, liquid metal, or gas. The succeeding chapters first study thermal hydraulics of pressurized water reactor (PWR), boiling water reactor (BWR), LMFBR, high-temperature gas-cooled reactor (HTGR), pebble bed reactor, and gas-cooled fast reactor (GCFR) cores and then deal with PWR, LMFBR, and HTGR heat exchangers. One of this book's great merits is the concentration in a single text of information on all these types of reactors, as contrasted, for instance, with more specialized American Nuclear Society (ANS) monographs on the thermal analysis of PWR, BWR, LMFBR, and HTGR. As expected, one drawback of the present approach is the lack of homogeneity in the treatment of various topics, including very different levels of sophistication. Significant differences in symbols, and even in the definition of terms between chapters could bring confusion in some student's mind, as could the frequent switch from British to SI units.

The PWR chapter by Neil E. Todreas, Massachusetts Institute of Technology (MIT), is well written and contains a great deal of information, correlations, and references, which could perhaps be overwhelming for students, although they are incomplete for engineers since proprietary models are mentioned but not described. There are a number of good problems, but the need for a detailed appendix with big tables of equations may be questionable.

B. Shizalkar (General Electric Company) deals with both steady-state and transient BWR thermal hydraulics in Chap. 3, which may be a little too long with tables somewhat too detailed for the noninitiated and also rather complex technical "jargon," even if the terms or abbreviations have been defined once before. Some figures are difficult to understand for the nonspecialist and would need more explanation. There are good descriptions of such phenomena as boiling curve or flow stability, but the uninitiated reader could perhaps get lost with detailed description of phenomena, which could have been omitted. As expected, terminology, data, and units are not always consistent with those of the previous chapter.

The first half of the LMFBR chapter consists in the explanation of one-phase heat transfer and fluid flow by R. Semeria et al. from Centre d'Etudes Nucléaires, Grenoble, France, with the second part on sodium boiling dynamics written by M. Grolmes and H. Fauske (United States). The first part is much easier to read and contains a good discussion of natural convection phenomena with sodium. The symbols are well defined but sometimes different from those used in English literature, and some figures are blurry and difficult to read. There are also minor misprints and maybe too few problems, but a good list of references. The second part on sodium boiling is difficult to follow for the nonexpert. It is too long and detailed and not clear enough for a textbook. There are nearly a hundred references and several problems; therefore, this may be useful to a specialist.

The next chapter on the HTGR by A. Shenoy and B. Shamasundar of General Atomic Company (GA), deals both with steady-state and transient performance of the helium-cooled reactor core. It considers the core thermal design bases and core design data for both coolant (flow correlations) and materials (properties including irradiation effects). After discussion of core thermal and flow analysis, the authors consider both anticipated transients and core and system response to accidents. There are a number of references, although maybe too many unpublished GA data. Most of the minor misprints are obvious, except perhaps for the temperature variation of the helium viscosity, which should read $\mu = 6.9 \times 10^{-4}\ T^{0.674}$ (p. 330). As is unfortunately the case in most nuclear engineering papers, there is a mixture of British and SI units.

In the second part of the chapter on helium cooling, E. Achenbach (Jülich, Federal Republic of Germany) deals with pressure drop, forced convection, and heat conduction in pebble bed reactors, with reference mostly to German reports. Discussion of the various heat transfer correlations for low Reynolds numbers is somewhat confusing, especially with the introduction of mass transfer analogy where terms are not always well defined, and German terminology is sometimes different from customary English terms. (There is no distinction between molecular diffusivity of heat and mass and no list of symbols.) Explanation of various expressions for equivalent thermal conductivity could have been shortened.

Part 3 on the GCFR is a joint effort by C. Baxi (GA, United States) and M. Dalle Donne (Kernforschungszentrum Karlsruhe, Federal Republic of Germany) with a large number of international references including work performed in Switzerland and in the United Kingdom. This chapter first discusses design considerations for GCFR fuel and blanket assemblies and then introduces correlations for pressure drop and heat transfer in various flow regimes. Experimental data are given with analytical considerations for artificial surface roughnesses used to improve the heat transfer from cladding to coolant. After a short description of computer codes, two examples of transient analysis are given: design basis depressurization accident and natural circulation cooling.

Chapter 6 is divided into three parts: R. Duffey (Electric Power Research Institute) on PWR steam generators, G. Robin (Commissariat à l'Energie Atomique, France) on intermediate heat exchangers (IHXs) and steam generators for LMFBRs, and P. Hunt and M. Lasarev (formerly of GA) on helium-heated steam generators. While steam generator design had often seemed less glamorous than core design, the importance of steam generators to plant economics and safety has become increasingly obvious for all reactor systems. After discussion of thermal design principles and of various commercial designs of PWR steam generators, a simplified formula is derived for the recirculation ratio. Thermal hydraulics of bundle support plates is discussed, and a sample computation of steam generator performance is provided. A good review is given of safety analysis of PWR steam generators, natural circulation, steam generator dryout, loading due to decompression after primary or secondary side failure, effect of secondary to primary flow leakage on reflood rate, and condensation induced pressure pulses. Like all chapters, there is a list of references and also a couple of problems.

The IHX in an LMFBR is a heat exchanger between the primary (reactor) sodium and the secondary (nonradioactive) sodium transporting the heat to the steam generator; the IHX usually operates above 500°C in both loop- and pool-type reactors. But most of the chapter's emphasis is on steam generators, which are always critical components of most LMFBRs because of the need to prevent both sodium/water and sodium/air reactions. Following a good discussion of the main design features of British, French, Russian, and U.S. steam generators, pressure drop and heat transfer correlations are given for the water side, since the sodium correlation utilized for the IHX design (given in the first part of this chapter) are still applicable. Comparison with test data is shown for the French reactor Phénix, and special correlations for Nusselt number and friction factor for water, steam, or two-phase mixtures are indicated for helically coiled tubes. Several interesting problems follow a broad international list of references.

A discussion of HTGR steam generators is included in the last chapter with emphasis on once-through helically coiled systems such as those for the (operating) Fort St. Vrain 330-MW(electric) reactor. Empirical correlations are given for gas-side (i.e., shell-side) heat transfer and pressure drop. Recommended Nusselt number and friction factor correlations are also given for the water side of the coiled bundles as compared to a straight bundle, for a number of conditions, but without comparison with test data and without indication of uncertainties. The chapter ends with short discussions of static and dynamic stability and of design limitations.

The book ends up with two useful appendixes, one on conversion factors and the other one on thermal properties of sodium. It is the only comprehensive textbook on the thermal hydraulics of all nuclear reactor systems, and thus it will serve as a useful single source of information in spite of some of its drawbacks, mostly due to the mosaic of authors. The editor is to be congratulated for having succeeded in convincing so many international experts to contribute. This book should be very useful for nuclear engineers involved in thermal or fast reactor design and also for teaching advanced nuclear engineering courses in graduate schools. The minor misprints and inconsistencies noticed could easily be corrected in the next edition.

G. B. Melese-d'Hospital obtained his PhD in fluid mechanics at Johns Hopkins University and subsequently worked on the first French gas-cooled reactors at Saclay from 1954 to 1957. After teaching nuclear engineering at Columbia University, he joined General Atomic Company in 1960 and has been involved in designs of gas-cooled thermal, fast, and fusion reactors since that time. Together with R. Katz, he is finishing the manuscript of an ANS monograph on thermal hydraulics of helium-cooled reactor systems. Dr. Melese-d'Hospital is a fellow and a past director of the ANS and is currently visiting professor of nuclear engineering at MIT.

Adsorption from Aqueous Solutions

Author	P. H. Tewari
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Reviewer	Arthur L. Reesman

This volume is the final product from a symposium of the same name that was held in March 1980 at the American Chemical Society meeting in Houston. It contains 12 research papers on various aspects of current research in adsorption from aqueous media.

Five of the papers are devoted to research in which oxide surfaces are the dispersed phase. Two of these deal with TiO_2-H_2O systems: One treats the system as a model colloidal dispersion; whereas, the other examines the adsorption of alkaline earth ions onto the TiO_2 surfaces. Another study involves the adsorption of transition metal ions onto amorphous FeO(OH) in the presence of several strong bonding anions (e.g., PO_4^{3-}, AsO_4^{3-}, and SeO_3^{2-}). Adsorption of oleate onto hematite surfaces as a function of concentration, temperature, and pH provided information related to the processes of flocculation, dispersion, and the formation of hydrophobic mineral surfaces. The final oxide research explores the interaction of uncomplexed Co^{2+} and complexed $Co(III)EDTA^-$ onto silica and alumina surfaces with the conclusion that hydrogen and -bonds are significant in adsorption in both cases.

The surface chemistry of chrysotile (asbestos) was studied to determine the optimum conditions for wet beneficiation processes that would reduce the airborne fibers relative to present dry processing. Another silicate, kaolinite, was used in a study of the adsorption of polyacrylamide and sulfonated polyacrylamide.