Book Reviews

Applications of Energy: Nineteenth Century. By R. Bruce Lindsay, Ed. Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pennsylvania (1976). 420 pp.

This is the second volume in the *Benchmark Papers on Energy*, of which R. Bruce Lindsay is the series co-editor. Like its predecessor, *Energy: Historical Development of the Concept*, it is an annotated collection of the classical papers from the middle and late 19th century. By the 1840's, the idea of energy was understood in a general way; in these papers, it is given sharper definition and is then applied to various branches of science.

The collection is divided into seven sections: I, The Pioneer Work of Helmholtz; II, Contribution of Clausius, Thomson (Kelvin), Rankine, Regnault, and Joule; III, Energy in Cosmical Physics, IV, Energy in Electricity and Magnetism; V, Energy in the Field; VI, The Science of Energetics; and VII, Progress in Equilibrium Thermodynamics. The authors are the great men of energy: Helmholtz, Clausius, Rankine, Kelvin, Regnault, Gibbs, Mayer, Joule, Ostwald, Maxwell, Planck, Poincaré, Raleigh, and Poynting. Lindsay, with his most illuminating annotations, weaves these classical papers together into a fascinating story, one that should be understood by all who are interested in energy.

Most of us nowadays take so much of the theory of heat for granted. It is hard for us to remember that there was a time when no one knew that I^2R was the heat generated by an electrical current or even that mechanical energy could be converted into heat, or that Helmholtz as a young, brash physiologist (not physicist) first generalized the principle of conservation of energy to nonmechanical transformations. All these things required flights of imagination as well as hard analysis and experiment. Sometimes there were false starts and paths that had to be retraced. All this is recounted in these papers.

I found the sections on the source of the sun's energy and the controversy over Ostwald's energetics particularly intriguing. Before nuclear energy, the source of the sun's energy was, of course, a deep mystery. Here we learn that Mayer suggested that bombardment by meteors was that source, a view expressed also by Kelvin. Incredibly, Mayer, realizing that celestial mechanics requires constancy of the sun's mass, comes very close to suggesting that mass and energy were interchangeable, thus in a way anticipating Einstein!

Or the bitter controversy between Ostwald and his extension of Rankine's "energetics," and Boltzmann and Planck, who with their more sophisticated understanding, were able to point to the flaws and inconsistencies in this seemingly simple approach—this one can also find here, in the original words of the protagonists, always with Lindsay's excellent commentary. But these are only a few of the vignettes that will reward the reader.

Here is a lovely book for those who wish to browse, to remember, to savor great moments in the history of energy. Let us hope that the forthcoming volumes in the *Benchmark Series* are as well done as is this one.

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About the Reviewer: Since his retirement from the directorship of the Oak Ridge National Laboratory a few years ago, Alvin Weinberg has applied his keen insight into socio-economic-scientific problems through the Institute for Energy Analysis, a part of the Oak Ridge Associated Universities. Dr. Weinberg has contributed much to the nuclear community since the earliest days of the Manhattan Project at the University of Chicago.

Boiling Liquid-Metal Heat Transfer. By O. E. Dwyer. American Nuclear Society, La Grange Park, Illinois (1976). 448 pp. $37.95.

Liquid-metal two-phase flow and heat transfer is a relatively recent research area. Its principal impetus has been problems connected with hypothetical accidents in the liquid-metal fast breeder reactor (LMFBR), but interest also stems from applications involving space power cycles, lithium-metal blankets surrounding fusion reactors, and liquid-metal magnetohydrodynamic power cycles. The author, who was one of the early contributors to the field of liquid-metal heat transfer, has chosen to concentrate on the literature up to 1972-1973 in pool boiling heat transfer, except for the first chapter dealing with incipient boiling superheat. Thus, the focus is quite narrow, since nearly all the applications of two-phase liquid-metal heat transfer have involved convective boiling rather than pool boiling. Furthermore, a number of new problems have arisen in this field, such as explosive boiling (vapor explosions), which may result from fuel-coolant interactions. Another important pool boiling case that has been omitted involves boiling in fuel-steel pools with internal heat generation.

Experimental work in the boiling liquid-metal area in the 1960's concentrated on pool boiling. The data were generally characterized by large scatter, both in the same apparatus and between different experimenters. This was particularly true for ΔT_{ib}, the incipient-boiling superheat, which varied from essentially zero to ~700°C for the alkali liquid metals. This was a matter of some concern relative to the early expulsion phase of a loss-of-flow (LOF) accident in an LMFBR in the early 1970's. A number of studies were run, both in the U.S. and in Europe, aimed at pinning down these effects. Various parameters were reported to influence ΔT_{ib}. Conflicting results were obtained, and the picture appeared to be hopelessly complicated until some definitive experiments by Holtz and Singer and by Henry established the dominating influence of small inert gas bubbles, which are always present in the wall cavities and in the circulating free stream in a reactor environment. The author gives a rather full account of these early experiments, but does not sufficiently emphasize the central conclusion stated above. Current practice is to assume that boiling is initiated when the wall temperature goes above the local saturation temperature in an LOF accident.

The second and third chapters are devoted to bubble growth, both far from any wall and at a heating surface. In liquid metals, bubble growth is quite fast, so that inertial effects are important. Several approximate solutions for isolated bubble growth are discussed. Unfortunately, practically no experimental data exist with which these data can be compared. Although pulsed x-ray techniques might be able to follow bubble growth in liquid metals, the problem has not been deemed sufficiently important to date to perform detailed studies. This is because a bubble growing in a reactor channel very quickly fills the cross section and therefore expands as a cylindrical bubble or a vapor slug. This aspect of bubble growth, which is the basis of the SAS code for sodium expulsion, is not treated.

The last three chapters deal with nucleate boiling, film boiling, and critical heat flux in liquid-metal pools. An excellent treatment is given of the Russian work in this field, which heretofore, except for the monograph by Subbotin et al., has been scattered throughout the literature. Most of these results have been correlated in terms of empirical dimensional equations, and theoretical approaches, such as the hydrodynamic theory (Zuber and others) of critical heat flux, are not particularly successful.

All in all, the author has performed a useful service in collecting a variety of scattered references covering the mechanics of liquid-metal pool boiling. The editing has been careful, although English and metric units (but not SI units) are mixed throughout. The specialist in the field will undoubtedly want to add this volume to his collection.

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About the Reviewers: S. George Bankoff is professor of chemical and nuclear engineering at Northwestern University, where he has been a member of the faculty since 1959. Dr. Bankoff received his early academic training at Columbia University and completed his graduate studies at Purdue University. He was associated with the Manhattan Project at both the Metallurgical Laboratories of University of Chicago and at the Hanford Engineering Works. He is currently the director of the Energy Engineering Council of the Technological Institute at Northwestern. He serves the U.S. Nuclear Regulatory Commission, Argonne National Laboratory (ANL), Los Alamos Scientific Laboratory, and the General Electric Company as a consultant. H. K. Fauske has been on the staff of ANL for more than two decades, with interests in heat transfer and fluid flow. He is presently associate director of the Reactor Analysis and Safety Division. Dr. Fauske received his academic training at the Bergen (Norway) Technic School and at the University of Minnesota.

Statistical Energy Analysis of Dynamical Systems: Theory and Applications. By Richard H. Lyon, with Chapter 15 written by Huw G. Davies. MIT Press, Cambridge, Massachusetts (1975).

This book is a comprehensive and well-written description of a relatively new method of dynamic analysis of coupled systems. Examples typically covered in the book are the steady-state, linear damped response of vibrating structures and acoustical systems, as well as combinations of the two. In the author's words, "SEA [statistical energy analysis] is the description of the vibrating system as a member of a statistical population or ensemble, not whether or not temporal behavior is random." This approach to the analysis of vibratory systems arises when one considers a trade-off in the analysis of complex systems. When performing a relatively thorough modeling of a real structure, such as a missile structure, numerous simplifications must be made when representing such components as riveted or welded joints, gusset plates, stringers, ribs, openings, etc., and the analyst must accept some uncertainty in the results. This is particularly true when higher vibrational modes are significant. As a trade-off, the analyst might consider the system description as having statistical properties as done in SEA. Uncertainty still remains in the predicted response, but two important advantages arise: The dynamic model can be greatly simplified, and a measure of the uncertainty can be developed. The latter is in the form of confidence intervals encountered in the theory of statistics.

SEA thus presents another approach the analyst can take when studying a system. This can be particularly advantageous in the early design stages. Furthermore, the method allows the use of experimental measurements on subsystems. As an alternate method of analysis, SEA has the above advantages but obviously has disadvantages. One of the strengths of this book is that both advantages and disadvantages are clearly pointed out.

To make full use of this book, the reader should have a good background in vibration theory and be familiar with impedance methods. Some knowledge of statistics is also helpful.

The style of the author makes the book easy to read. There is a good blend of discussion of the practical aspects of the topics as well as a thorough presentation of the mathematics. The book is divided into two parts, with a separate bibliography for each. Roughly speaking, Part I covers the theory of SEA, while Part II concentrates on applications. No problems are included at the ends of the chapters, so use as a textbook is limited. However, the book is primarily a monograph as an introduction of SEA to practicing engineers.

The contents of the book by chapter are:

Part I. Basic Theory

1. The Development of Statistical Energy Analysis
2. Energy Description of Vibrating Systems
3. Energy Shared by Coupled Systems
4. Estimation of Response in SEA