J. Fluid Mech. (1981), *vol.* 112, *pp.* 498–501
Printed in Great Britain

REVIEWS

Power from Sea Waves. Edited by B. COUNT. Academic Press, 1980. 449 pp. £23.60.

This volume is based on the proceedings of a three-day conference organized by the Institute of Mathematics and its Applications at the University of Edinburgh during June 1979. During the past decade the cost of energy has risen dramatically with the cost of petroleum, and alternative sources of energy are now being examined in many countries. Forms of renewable energy include solar energy, wind energy and ocean-wave energy, and it is with the last of these that the present volume is concerned. All the contributors except Budal and Falnes are from United Kingdom, which is particularly exposed to wave energy, and which would be a principal beneficiary if this form of energy could be harnessed.

The chapter headings are as follows. I.1, The place of wave power in the government's energy programme, by Sir H. Bondi; I.2, Wave power – a problem searching for a solution, by B. Count; II.1, Synthesis of a directional wave climate, by J. A. Crabb; II.2, Synthesis of wave climate, by N. Hogben and B. L. P. Miller; II.3, Computer calculations of waves from wind fields; II.4, The prediction of device performance, by D. Mollison; III.1, Use of potential flow theory in evaluating wave forces on off-shore structures, by R. G. Standing; Some analytical results for two and three dimensional wave-energy absorbers, by D. V. Evans; III.3, Wedges, plates and waves – some simple mathematical models of wave power machines, by P. C. Parks; III.4, The hydrodynamic interactions of spherical wave power devices, by M. J. L. Greenhow; III.5, Mathematical analyses related to the Vickers Project, Part I by Sir James Lighthill, Part II by M. J. Simon; III.6, Interacting point absorbers with controlled motion, by K. Budal and J. Falnes; III.7, Aspects of the French flexible bag device, by R. V. Chaplin and M. J. French; III.8, Device characterisation, by E. R. Jefferys; IV.1. The future of wave energy, by C. O. J. Grove-Palmer. (At the conference there were some lively discussions but these are not included.)

Readers of the *Journal of Fluid Mechanics* will be most interested in parts II and III which are concerned respectively with the calculation of ocean waves from wind data and with the application of hydrodynamical theory, and which occupy 400 pages of these proceedings. The two general talks in Part I set the stage. Bondi argues for a study of wave energy and makes out a convincing case without overstatement, while Count gives a survey of devices currently being studied, with some general considerations about wave-power systems.

In part II, Draper describes how the study of sea waves only developed in earnest during and after the Second World War. The problems of measurement and interpretation have been severe but reliablity has gradually improved through the cooperation of theoretician, instrumentalist and user. There is, however, still a long way to go before we can be satisfied. Crabb points out that there are as yet few sites for which wave data have been collected over a long time, and a reliable evaluation of forecasting methods is thus difficult. He shows that nevertheless considerable progress is possible. To predict swell he uses dynamical theory: the wind in the storm area determines the wave spectrum which then disperses away from the storm area and

which is compared with local observations. Hogben and Miller use statistical methods without dynamical theory; if these can be made to work they will have the merit of simplicity. Golding uses dynamical theory and presents many of the corrections which must be made if the waves on the shore are to be estimated with sufficient accuracy. Much work and much thought has gone into this group of papers, but much basic information is still lacking. Mollison finds that as yet only a poor estimate can be given of the expected long-term wave-power average. But even if it were known (and he attempts to give an estimate) it would still be difficult to predict the output of a given wave-energy device. These difficulties are not insuperable, however, and his estimates suggest that wave power can become competitive. This paper is a wide-ranging and impressive contribution.

Part III treats problems which will be more familiar to readers of the *Journal of Fluid Mechanics*. Standing examines linear potential theory and shows that it is applicable to the calculation of wave forces, with some reservations. He describes calculations on the Salter Duck and the submerged duct in various conditions, and the results often agree with model experiments but many parameters are involved and more work is needed. Evans in his paper gives reasons why a body which is long in the direction of the wave crests is a better energy absorber than a thin body heading into the waves. He goes on to analyse the effect of finite width, the performance of a thin 'clam' device and of the submerged circular cylinder, and the interaction of an array of absorbers. Parks gives a mathematical analysis of thin wedges and plate machines, Greenhow of spherical devices, Lighthill and Simon of the Vickers Project. (Lighthill had already published an impressively long account of his work in *JFM*, Simon describes recent three-dimensional developments.) These papers are excellent examples of the use of powerful mathematical methods, together with model experiments, to illuminate the various problems.

Budal and Falnes describe the Norwegian system which involves controlled motion of the absorbers, and present new model experiments. Chaplin and French describe their flexible-bag device, with some brief theoretical arguments. Jefferys observes that the equations of motion of bodies in waves contain convolution terms, and considers the approximation of such terms by differential equations. In the last few pages Grove-Palmer summarizes progress so far, and looks into the future.

This volume describes an intermediate stage in the investigation of power from sea waves. The first stage consisted of theoretical calculations and model investigations starting with simple configurations. From these a number of ideas for possible designs have emerged, and have been subjected to much more detailed theoretical studies and model experiments. This is the stage with which the present volume is concerned. Since the work is no longer concerned merely with simple geometrical shapes, the results involve several parameters and are not easy to grasp. At the same time there have been calculations to estimate the wave climate at favourable sites from wind information. The contributors have done their work well and have described it in papers of high quality. Much useful knowledge and understanding has been gained in a short space of time, and this will be of great value during the next stage (if it is ever undertaken) which will be concerned with engineering problems.

F. URSELL

Fluid Flow Phenomena in Metals Processing. By J. SZEKELY. Academic Press, 1979. 437 pp. £26.60.

Brewing and metallurgy must be among the longest-established accomplishments of the human race, both involving fluid-mechanical practices of some complexity, both developed empirically and still owing very little to the fluid science which has recently emerged in a mere two centuries or so. There seems to be an historical rule that, the longer established a procedure, the less it tends to be subjected to scientific scrutiny. In contrast, an upstart such as aviation gets an exaggerated share of attention from fluid-dynamicists.

Why should this be? Is it that metallurgical practice is so familiarly available in the background that we take it for granted, along with so many other things vital to civilized life, like piped water or sewage disposal, and therefore it lacks the glamour necessary to attract talented young scientists at a formative stage? Or does its difficult, interdisciplinary nature repel scientific approaches? Probably much of the answer lies in economics, the plain fact that technology only calls on science if empiricism fails to be sufficiently profitable or if the competition gets a march ahead. But industrialized nations now face a few factor, the rise in the cost of energy to a point which demands serious scientific appraisal and optimization of industrial procedures in order to save energy. Industrial metallurgy is a great energy user and perhaps this explains why at long last sciences such as fluid mechanics are being brought to bear upon it, as evidenced by Szekely's pioneering and timely volume. If I go on to be rather critical of the book in detail, let not this detract from the service which the author has done in drawing attention to the importance of applying fluid-mechanical principles in metallurgy and to the wealth of opportunities for fluid-mechanical research in that field.

JFM readers should note that the book is a fairly elementary textbook, and the treatment of advanced matters approaching the research frontier is necessarily brief and superficial. Nevertheless, by its insistence throughout on exemplifying even the elementary fluid principles by applications in metallurgy (rather than the ones that we are used to in familiar fluid-dynamics texts) and by its outline of complex problems of current interest, especially in the later chapters, it allows the reader with imagination to appreciate the scope for important and challenging work in the field. It is clear that Szekely, though ostensibly writing for senior undergraduate or masters students, was also hoping that the book would have some propagandist effect on the fluid-mechanical research community. His enthusiasm for his subject and for its expansion comes over very clearly. Unfortunately that same enthusiasm also generates some of the book's weaknesses, where haste has led to the setting down of ill-ordered arguments, or even outright errors or inconsistencies.

I am bound to say that, despite the obvious benefit of the supporting metallurgical examples, a metallurgy student wishing to learn the relevant basic fluid mechanics would do better to use one of the many excellent elementary texts which have been written by people of long experience in the exposition of the subject, rather than the first half of Szekely's book. The help of several people in reading the manuscript is acknowledged by the author; one wishes they had been more penetrating and forceful in their comments. For instance, chapter 2, which attempts to cover traditional engineering fluid mechanics, is with its infelicities and outright errors highly con-

fusing. One could cite many examples. A typical symptom of haste is figure 2.6.2, labelled 'photograph of a shock wave', a zebra-like spectacle to the uninitiated, who will have no way of knowing that he is contemplating an interferogram or of interpreting its significance. Figure 6.3.10, showing natural convection, is labelled an interferogram, but the ignorant reader has no way of knowing that horizontal is vertical.

Chapter 3 covers more formal fluid mechanics, including the Navier–Stokes equation. It is mostly correct but somewhat unilluminating. For instance, in the context of a subject where circulating flows are common, often driven by rotational force fields, as in the magnetohydrodynamic areas of metallurgy, it is disappointing to find that vorticity is introduced without any hint as to why physically it is such a vital concept in fluid mechanics. There is no statement as to when and why irrotational motion will or will not occur. The chapter ends with a long and generally satisfactory section called 'Exact solutions of the Navier–Stokes equation' – except that they are mostly *approximate* solutions, using the boundary-layer model, etc.

Chapter 4 concerns the turbulent flows which are so prevalent in industrial metallurgy and gets off to a bad start by stating that Navier–Stokes does not apply to turbulent flow. To his credit, however, the author casts doubt on the physical realism and reliability of many of the semi-empirical computational treatments of turbulence in current use for predicting velocity fields and mixing and dispersion (particularly important themes in the metallurgical context). The chapter does not take these treatments very far and merely directs the reader to some of the literature.

The book gets more interesting to the *JFM* reader from chapter 5 onwards, as Szekely turns his attention to the more complex problems peculiar to metallurgy, although in most cases space allows only a perfunctory treatment. Chapter 5 refers to some of the many metallurgical systems dominated by magnetohydrodynamic effects. Chapter 6 is the only place in the book where the heat transfer phenomena which play an enormous part in metallurgy are mentioned. The book would perhaps have been better balanced if thermodynamic factors had received more attention. The chapter also deals with surface tension effects in a section which this reviewer found novel and fascinating. Chapters 7 (covering two-phase solid/fluid systems) and 8 (covering two-phase fluid/fluid systems) range very widely and, though interesting, are inevitably rather episodic. The book ends with chapter 9 on jets, chapter 10 on measuring and modelling techniques, and what the author calls a 'postface' in which he enthuses about the scope for further developments in metallurgical fluid mechanics research and says: 'It is hoped that this volume will contribute to stimulating these developments.' I hope so too; until better books emerge this one deserves wide circulation.

J. A. SHERCLIFF