REVIEWS

Research Frontiers in Fluid Dynamics. Edited by R. J. SEEGER and G. TEMPLE. Interscience, 1965. 738 pp. £11 10*s*.

Basic Developments in Fluid Dynamics. Edited by M. HOLT. Academic Press, 1965. 447 pp. £7.

These two collections of survey articles reflect the need to take occasional stock of the state of knowledge of the various branches of fluid dynamics. It is difficult to keep abreast of developments in one's own chosen field of interest, and well nigh impossible to keep in touch with other fields, so that pre-digested accounts of what has happened can be of great value. Writing a survey is no easy task and demands skill in the organization and presentation of material, a deep understanding of the field, and a willingness to spend time reading the literature; and the relatively few people who meet these conditions ought to be encouraged to give the writing of surveys high priority. Unfortunately such articles are not normally given equal weight with 'original' papers in a man's list of publications and he undertakes survey writing perhaps at some cost to the advancement of his career. This is illogical, as well as being a handicap to science, since the intellectual difficulty of writing a coherent and understandable account of the state of knowledge in a certain field is at least as great as that of making a small advance on a restricted front; and the talent required for the former is a good deal less common. All the more credit to the two sets of editors, then, for having persuaded so many authoritative authors to accept and carry out the task.

Research Frontiers has surrounded the survey articles with a screen of talk about 'exciting research vistas', 'panoramic views' and 'telescopic sweeps' in this 'dynamic field' by 'world famous authorities'. These dramatic aids to interest are fairly harmless although the editors' tendency to equate excitement with novelty of conditions is more than merely an irritant. 'Above all, the student of today needs to consider modern fluids, i.e. real fluids, not merely the idealized concepts of yesteryear's hydrostatics, hydrodynamics and aerodynamics.' True enough, but ordinary air and water are real fluids which move in ways which are not wholly understood, chiefly because the underlying mathematical problems are non-linear and remain unsolved. It would be regrettable if the graduate students for whom the book is intended got the impression that the only exciting problems are the new ones. The tendency for researchers to jump on any bandwagon which carries the label of modernity is strong enough, without being fed by this kind of over-valuation of the extreme and the unusual.

The 20 articles in the book have grand general titles, although most of the authors sensibly confine themselves to particular aspects and topics. Since no table of contents other than the titles of the articles is provided and none of the articles has a summary (this depature from the practices of yesteryear will not become general, I hope), it is difficult to see quickly just how the authors do restrict their scope. Here are the titles, for what they are worth, and their authors:

Engineering Aspects (29 pp.), by W. R. Hawthorne.
Mathematical Aspects (40 pp.), by M. H. Rogers, D. W. Moore and J. B. L. Powell.
Numerical Analysis (46 pp.), by Harry Polachek.
Molecular Theory of Fluids (29 pp.), by H. S. Green.
Viscoelastic Fluids (39 pp.), by R. S. Rivlin.
Anomalous Viscosity (27 pp.), by M. Riener.
Second-order Effects (22 pp.), by M. Reiner.
Shockwave Phenomena (19 pp.), by D. C. Pack.
Transonic Flow (38 pp.), by K. G. Guderley.
Asymptotic Solutions in Hypersonic Flow (34 pp.), by N. C. Freeman.
Magnetofluid Dynamics (24 pp.), by C. K. Chu and Harold Grad.
Application of the Boltzmann Equation to Low-density Flows (42 pp.), by G. N. Patterson.
Low-Temperature Phenomena (20 pp.), by D. ter Haar.
High-Temperature Phenomena (36 pp.), by J. D. Teare.
High-Density Phenomena (37 pp.), by John S. Dahler.
Meteorology (39 pp.), by O. G. Sutton.
Oceanography (22 pp.), by A. R. Robinson.
Free-surface Flows (30 pp.), by John V. Wehausen.
Astrophysical Phenomena (107 pp.), by Lawrence H. Aller.
Fluid-dynamical Problems Associated with Interplanetary Space (36 pp.), by E. N. Parker.

Once a reader has got past the editorial excitement and the uninformative titles (the first of which takes the prize for breadth), and has reached the point in an article at which the author says what he really proposes to discuss, the quality of the book begins to show. The authors are all distinguished research workers, and have a good deal to say that is of interest. Some of the articles are in the nature of general introductions to broad fields, and are likely to be useful as preliminary reading for those who contemplate active work in these fields. Others are more specialized and are likely to be read mainly by those already involved in the field concerned. Many of the articles are concerned with the relation between macroscopic properties of a fluid and the molecular structure—an aspect which is not well covered in the literature of fluid dynamics. The kind of fluid dynamics that involves conventional fluids and common physical conditions is not well represented, and the volume is perhaps best regarded mainly as a collection of introductions to 'peripheral' subjects unlikely to be discussed in current text-books. The standard of the writing is generally high, and, taken as a whole, this is a valuable book. Can the editors help us to discover what is in each article, thereby making the book even more valuable, by collecting and making available summaries of the articles?

Basic Developments is a more straight-forward and less ambitious collection of five survey articles 'on topics of current research interest', and is the first of a series of such volumes. The editor has asked each author to write a connected description of his own and related research. Such articles are inevitably rather specialized, and it is a matter of chance whether one finds in these five articles anything of immediate or potential relevance to one's own research. The titles of the articles and their authors are:

The Numerical Solution of Problems in Gas Dynamics (126 pp.), by O. M. Belotserkovskii & P. I. Chushkin.
Bluntness Effects in Hypersonic Small Disturbance Theory (112 pp.), by J. P. Guiraud, D. Vallée & R. Zolver.
The Stability of Parallel Flows (60 pp.), by W. H. Reid.
Blast Wave Theory (68 pp.), by A. Sakurai.
Laminar Boundary Layers on Cambered Walls (60 pp.), by F. Schultz-Grunow and W. Breuer.

The first article is a long and, I should guess, very valuable account of recent work in U.S.S.R. on the use of numerical methods and computers for the solution of a wide range of gasdynamics problems, and is divided into three sections, on the method of finite differences, the method of integral relations, and the method of characteristics. The other articles are of a type which can reasonably be inferred from their titles and the names of the authors. All are distinctly mathematical. The one closest to my own field of interest, by Reid, is a clear and scholarly account of known results obtained from the Orr–Sommerfeld equation, and contains some useful improvements of method and presentation.

With all volumes composed of survey articles, like these two, there is doubt about whether individuals should buy them. People with broad interests and a taste for casual reading might well purchase *Research Frontiers*, since it contains a number of short accounts of interesting topics suitable for a non-specialist; but not many individuals are likely to see *Basic Developments* as worth the price. It may be that the most appropriate place for survey articles, unless they are part of a group with a unifying theme, is in a journal, for then no new decision regarding purchase is required from either individual or librarian.

G. K. Batchelor

Introduction to the Theory of Flow Machines. By A. Betz. Pergamon, 1966. 281 pp. 75*s*. **Fluid Mechanics of Turbomachinery.** By S. L. Dixon. Pergamon, 1966. 213 pp. 25*s*. **Axial Flow Turbines.** By J. H. Horlock. Butterworth, 1966. 275 pp. 97*s*. 6*d*.

The appearance of this trio will be welcomed by students of turbomachinery, a subject rather neglected by publishers. The first is a very general survey of all types of flow machines by Prof. Betz, a colleague of Prandtl's at Göttingen and now the doyen of aerodynamics in Germany. The other two are from the thriving turbomachinery school which Prof. Horlock built up at Liverpool University before he moved to Cambridge, for Mr Dixon was a member of his staff. Dixon's is an undergraduate text-book on turbomachinery and Horlock's is a specialist treatise on modern design methods for advanced students and engineers.

The original German version of Betz's book was published in 1959. As it is only intended to serve as an introduction to the theory it has been intentionally oversimplified to emphasize the unity of a diverse subject. The result is a masterly survey of the overall behaviour of turbomachinery in terms of fundamental mechanics and thermodynamics. The four main sections cover general considerations, ducts, cascades, and flow machines, together with a useful appendix comprising physical, aero and thermodynamic data, a clear list of symbols and an excellent bibliography. The aim throughout has been to explain the fundamentals of internal aerodynamics and its applications to aerofoil, cascade and flow machines. For a re-edited version it is perhaps slightly dated—for instance, modern ideas about boundary layers and secondary flows are missing and also actuator disk theory for axial machines, but the spectrum of topics and machines covered is unusually broad for one book. Some formal proofs such as Bernoulli's equation and Poiseuille flow in a pipe are omitted, but this is forgivable because there are so many unusual things that the book contains. Subjects such as diffusion, mixing, flow through contractions and the fundamentals of potential flow applied to cascades and aerofoils are excellent and it is salutary to be reminded, for instance, that it was as early as 1915 that Prandtl first investigated rotating stall. There are some cases perhaps where oversimplification may have been carried further than necessary; for instance, the axial flow rotor is considered together with a conical diffuser but not with an associated set of stator blades. Centrifugal rotors are considered in isolation from the casing in which they would normally operate. The text has been well translated, apart from a few minor errors of usage like blade 'pitch' instead of the term 'space' now commonly used and 'water shock' presumably for 'Wasserstoss'. Admittedly symbols are always a difficulty in such a wide-reaching book but some of those chosen are little used today. On the whole the original clarity has come through well in translation and the many illustrations are first-class.

However, such criticisms are only of minor detail, for the whole book represents the experience and wisdom of a very distinguished pioneer of aerodynamics. This introduction can be strongly recommended to anyone wanting a birds-eye view of turbomachinery from water-wheels to steam turbines and from windmills to rockets.

Dixon's book is a competent account of the fundaments of turbomachinery for undergraduates. The emphasis is mainly on axial-flow gas turbines and compressors, although brief mention is made of steam turbines, pumps, water turbines, and radial compressors. It comprises eight chapters on dimensional analysis; fluid mechanics and thermodynamics; two-dimensional cascades; axial-flow turbines; axial-flow compressors, pumps and fans; three-dimensional flow in axial machines; centrifugal pumps, fans and compressors; and radial-flow turbines. Each chapter contains a useful bibliography and there are few problems for students to tackle. It describes briefly the most important design theories including cascade, aerofoil and actuator disc methods, quoting NGTE and Horlock extensively. The emphasis is on thermodynamics and compressible-flow theory and relatively little is said about the more prosaic but equally difficult field of incompressible flow in pumps and water turbines. For the more difficult case of radial-flow machines the interaction of casing and rotor upon performance is not discussed in detail although it is of prime importance in practice. Nevertheless, the fundamentals are well presented and generally applicable. The book is good value for undergraduate students and may also be of some interest to engineers who wish a simple refresher.

Horlock's book is much more detailed and advanced than the other two and provides an authoritative account of modern theory and design techniques for axial-flow turbines, complementing his excellent book on axial-flow compressors by the same publishers in 1958. It is intended for final year students, research staff and all engineers interested in the aerodynamics of gas turbines. It deals comprehensively not only with two- and three-dimensional aerodynamic theory and thermodynamics, but also with cooled turbines and stressing problems. Although here and there fleeting comparisons are made with steam-turbine data and with head/flow characteristics of water turbines, the emphasis of the book is upon axial-flow gas turbines. It is particularly well documented, drawing mainly from NGTE, MIT, NACA, and Cambridge and Liverpool University sources. It contains a bibliography of 170 important references. Although theory is thoroughly described it is clear that considerable empiricism is still necessary to obtain the best designs. This is indeed the state of the art and we are grateful to the author for collecting such a wealth of material and by careful comparison extracting the best general rules where possible. The longest chapter, on cascade performance, is particularly valuable in this respect in collecting test data from world literature. The chapter on three-dimensional design methods, using mainly radial equilibrium theory or actuator disc theory or various adaptations of these theories, is relatively brief and no comparisons with experiment are provided to enable one to judge their efficiency. It is clear, however, from the subsequent chapter on off-design performance and multi-stage turbines that semi-empirical corrections must be applied to make even the best design methods work. The eight chapters deal with basic thermo- and fluid dynamics, two-dimensional flow in turbine stages, turbine cascade data, potential cascade theory, three-dimensional turbine design methods, low specific speed axial-flow turbines including transonic and supersonic turbines, and cooled turbines. There are four valuable appendices on stressing, preliminary design criteria, specific heat data for gases, and numerical methods of streamline analysis. The book is clearly written and copiously illustrated with graphs and diagrams and in addition to the bibliography has comprehensive author and subject indexes. Although relatively expensive, this is a valuable book and can be strongly recommended.

S. P. Hutton

Low Reynolds Number Hydrodynamics. By J. Happel & Howard Brenner. Prentice-Hall, 1965. 553 pp. £6.

The study of slow motions of a viscous fluid is one of the less fashionable branches of fluid mechanics. Yet, as illustrated by the examples listed in the introductory chapter, low Reynolds number flows are of enormous practical importance in many fields of science and technology. The motion of gases and liquids through packed beds and porous media and the flow of suspensions are problems that constantly face the chemical, civil and mining engineer. Lubrication theory has a practical importance that is difficult to exaggerate. Meteorologists and cloud physicists study the growth of raindrops by collisions between small droplets, and many problems of atmospheric pollution require a knowledge of how small particles move through fluids. In the currently fashionable subject of biofluidmechanics, a low Reynolds number occurs in many important aspects of blood flow in the body and air flow in the lungs. The list of examples can be readily extended. Indeed, some modern work in aerodynamics overlaps the régime of low Reynolds number flow because of the high viscosity produced by low densities and high temperatures.

Many of the problems to be solved are fascinating, and difficult. And although the study of slow viscous flow was initiated over 100 years ago, new and intriguing phenomena are still discovered. To mention a couple, there is the tubular pinch effect of Segre & Silberberg (still unexplained) and the strange behaviour of falling clusters of spheres discovered and explained by B. J. Mason and his colleagues, both found during the last seven years. In fact, some of the phenomena have a mysterious element about them and progress has been held up not only by an inability to solve the equations of motion but by the knowledge that the equations of motion seem unable to predict the observed phenomena without appeal to extraneous principles like minimum energy dissipation, which should if true be consequences of the equations of motion. An example is the fall of a sphere down a close-fitting cylindrical tube studied by Christopherson and Dowson. Moreover, one of the major advances in the general theory of asymptotic expansions during the last decade, namely the matching of inner and outer expansions, was stimulated largely by the Stokes and Whitehead paradoxes for the flow past a body at small but non-zero Reynolds numbers. There is certainly a need for a comprehensive and stimulating account of low Reynolds number fluid mechanics, if only to focus attention on the many difficult problems that exist and the work that remains to be done, besides trying to unify and assess the present knowledge.

However, the present book, despite its length of 534 pages, is concerned mainly with only one particular topic in the field, namely the Stokes or creeping flow past a particle when the fluid inertia is neglected. Claims are made in the preface that the book represents an attempt to bridge the gap, between classical hydrodynamics which deals with perfect fluids which unfortunately exert no forces on the particles past which they move (*sic*), and practical subjects like fluidization, etc., by providing at least the beginnings of a rational approach to fluid particle dynamics, based on first principles. But these should be ignored, for the meat of the book is a detailed and exhaustive account of some problems of Stokes flow. With the fluid inertia neglected, the equations of motion for a uniform viscous liquid become linear and the problems reduce essentially to solving the biharmonic equation with boundary conditions given on fixed surfaces. The mathematical problems are not easy, and indeed only approximate solutions or expressions as infinite series are known except for the sphere and ellipsoid in an unbounded fluid. In chapters 2 to 7 inclusive, a lengthy discussion is given of many of the problems in this field that have been investigated. There is an account of general results, such as a reciprocal theorem and the fact that the forces on a body are described by intrinsic tensors so that some general conclusions can easily be obtained using symmetry arguments, and there is a vast amount of detail on the solutions for bodies of different shapes and in the presence of walls.

The theoreticians working on problems of Stokes flow with rigid boundaries are likely to find these six chapters useful, as they contain in one place much material that at present is scattered throughout the literature. The more practical scientist is unlikely to find them of much value, except perhaps for the data on wall effects for the motion of a single particle given in chapter 7. Indeed, the non-mathematical reader will find the going hard, since although there is nothing deep or difficult about the mathematical techniques employed, a good familiarity with polyadic algebra, curvilinear co-ordinates and eigenfunction expansions is demanded and there is little concession to the reader whose mathematics is weak. The part of the subject covered is certainly that part which is most amenable to mathematical analysis and in which solutions can be ground out with much labour. However, it is one of the dullest parts and the view of low Reynolds number hydrodynamics given by these six chapters will not change the attitude that it is a dull, pedestrian subject in which a great deal of work produces little of real scientific interest. Even within the restricted range of particle motion in Stokes flow, there are some gaps in the coverage and some of the space devoted to analytical details could perhaps have been better spent on considering the motion of non-spherical particles in shear flows, or the collision and interaction of two spheres in non-uniform flows, or the motion of deformable particles.

Chapter 8 on flow through beds of particles or porous media is mainly independent of and on a somewhat different level to the preceding chapters, being on the whole a brief survey of practical problems like sedimentation of suspensions, sludge flow, flow through porous media and fluidization. There is some use of general formalism in a description of multiparticle systems by a 'grand resistance matrix', but it is not shown how this concept is of any practical use and it is in fact concluded that for practical problems there is as yet no alternative to empirical methods. The ninth and last chapter deals with the viscosity of suspensions. There is a derivation of the Einstein formula and a brief review of the extensions to concentrated solutions and non-spherical particles. The proof of the Einstein formula is rigorous, and it eliminates difficulties that appear on a close inspection of Einstein's derivation; but a price is paid in the form of more formal manipulation.

To sum up, this book contains an account of the motion of small particles through uniform viscous fluids at rest replete with gory detail. For accounts of lubrication theory, the effects of inertia, flows with free surfaces, motions of non-uniform fluids and other aspects of low Reynolds number hydrodynamics which are more interesting, the reader must look elsewhere.

P. G. Saffman

Theorie der Schallnahen und der Hyperschallströmungen. By J. Zierep. G. Braun, 1966. 193 pp. DM. 46.

Nichtstationäre Probleme der Gasdynamik. By R. Sauer. Springer Verlag, 1966. 195 pp. DM. 36.

After the favourable reception of his book, *Vorlesungen über theoretische Gasdynamik* (see *J. Fluid Mech.* **16**, 1963, p. 160) Professor Zierep felt encouraged to follow up his earlier general introduction into classical gas dynamics with a second volume. This is an introduction into two areas of modern gas dynamics, namely steady transonic flows and steady hypersonic flows. After a general discussion of the special problems of 'mixed' flows and of the basic equations, the various forms of the transonic similarity law (v. Kármán, Guderley, Oswatitsch) and its extension by the author for flows with heat addition are described in great detail. Of special interest is an account of the author's work on the mathematical behaviour of a shock wave near a curved wall in inviscid flow.

A description of Guderley's solutions for two-dimensional flow is followed by Spreiter's treatment of the flow as a parabolic problem. Finally, the scope of the integral equation method due to Keune, Oswatitsch and Zierep is illustrated by examples, including flows with trailing edge shocks. The second part of the book on hypersonic flows is of less intrinsic interest to readers outside Germany since there are a number of text-books on this subject in the English and American literature.

As in the earlier volume a good deal of information is given in the form of exercises, which ought to stimulate the reader. The book is a good introduction for graduate students interested in transonic flow problems.

Professor Sauer's *Einführung in die theoretische Gasdynamik*, which first appeared in 1942, has seen three German editions. Now the author has decided to publish in book form his course of lectures on 'Unsteady problems of gas dynamics' which he has given over many years to engineers, applied mathematicians, and physicists at the Technical University of München. The book covers (i) basic ideas, (ii) linear theory of small perturbations, (iii) non-linear theory of one-dimensional plane (isentropic) pressure waves, (iv) extension of (iii) to one-dimensional flows with variable cross-section, (v) shock waves, (vi) non-linear theory of two-dimensional and three-dimensional pressure waves.

The aim of the book is the development of numerical methods (difference equations; marching in time) for the calculation of unsteady flows. The book is self-contained since the required background knowledge of gas dynamics and mathematics is given and illustrated by many examples. Like its predecessor it is an excellent introduction to the subject for a student in his second or third year who can read German.

K. W. Mangler