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REVIEWS

Hydrodynamics, by DANIEL BERNOULLI, and **Hydraulics**, by JOHANN BERNOULLI. Translated from the Latin by T. Carmody and H. Kobus. Dover, 1968. 456 pp. $15.

The Bernoulli family is one of the most famous in the history of science. They were forced to leave Antwerp in 1583 to escape massacre, and a century later three consecutive generations produced in Basle a series of celebrated mathematicians. They were given to stealing each other's results and the family rows that ensued were conducted with even more than the customary venom. This volume is concerned with the work of Daniel (1700–1782) and of his father Johann (1667–1748). The former is the more important and occupies 342 pages out of the total 451.

The volume begins with an illuminating preface by Hunter Rouse. In the Bernoullis' time the calculus had been established, but the principles of energy and of momentum were imperfectly understood. It was left to Euler to formulate what we now know as Bernoulli's equation. Consequently both Daniel's and Johann's books do not go very far, and in the fashion of the time they are distinctly long-winded. However, Daniel was a humane man. His discussion of flow out of a U-tube with unequal arms, typical of his problems, leads to stodgy algebraical results, on which he comments: 'Since these equations are somewhat involved we will not tarry in the general contemplation of them'. Would that his successors had more carefully followed his example. He interprets the term hydrodynamics very widely, and he even manages to include some remarks on the theory of treadmills.

Johann's book is an astonishing example of plagiarism. The date is false, suggesting that the book appeared before Daniel's, which it did not. Indeed, there is no evidence that the former had written anything of importance on fluid mechanics before his son's book was published. Nevertheless, the book is worth translating because his conception of fluid pressure was more accurate. Moreover, he attempted some difficult problems, notably the last. A tube, kept full of water by the thumb placed over the top, is held vertically with the bottom end immersed in a large basin of water. After the thumb has been quickly removed, how far below the level in the basin will the free surface in the tube momentarily descend?

The quality of the translation is deplorable. The Bernoullis' Latin though clumsy in expression is not difficult to understand, but the translators' knowledge of the language is limited and their feeling for English style is non-existent. In the first chapter of the *Hydrodynamics* Daniel writes in a rather general, discursive manner, and his sentences are sometimes long and involved; the translation reproduces his syntax closely and unintelligently, and the English that results is at best unreadable and at worst unintelligible or meaningless. In the succeeding chapters and in the *Hydraulics* the language of the original is more succinct, and here the translators have been rather more successful.

In some places the translators have clearly misunderstood the Latin, while in others their version is couched in such grotesque and uncouth English that

it is difficult to know what they think it means. How big, for example, is a stream which is 'seldom not contracted to almost one half' (p. 327)? (What Johann actually says is 'not infrequently contracted to about a half'.) When they make Daniel say 'let us disregard the variations of the motion... because ...the motion...is as much not uniform' (p. 183), common sense will realise that he must have meant 'because the motion is practically uniform'; reference to the Latin will show that this is what he did in fact say, and generosity may perhaps forgive the translators their ignorance of the Latin idiom 'tantum non' and their rendering of it by the meaningless gibberish 'as much not'. But sometimes the damage is more serious: who can disentangle 'even at some time Men most perspicacious in known theorems confessed openly that they cannot persuade themselves so, nor do they consider that [the theorems] are about to be confirmed by experiments' (p. 4), and can realise that it means 'sometimes even the most perspicacious men, when they heard my theories, confessed openly that they could not accept such ideas and did not believe that the theories would be confirmed by experiment'?

A glance at random through the book reveals a profusion of elementary mistakes on almost every page. Daniel's preface alone (23 lines in the original, 24 lines in translation) contains six mistranslations. In the first few pages the translators show themselves unfamiliar with several common Latin constructions, and they even commit the notorious schoolboy howler of mistaking 'forte' ('by chance') for 'fortiter' ('strongly') (p. 4). It is, however, fair to say that in spite of these displays of gross ignorance it is usually possible to make out the general sense of the Bernoullis' meaning, though anyone with a moderate knowledge of Latin will find the original much more readily intelligible than the translation. In his preface Daniel quotes the Latin proverb about 'unwilling Minerva', which, as readers of Cicero (*de Officiis* I. 110) will recall, suggests that one should not undertake a task for which one lacks the talent. It is a pity that the translators did not take this dictum to heart before embarking on a project for which they were so obviously unqualified.

The volume is beautifully produced. The form of the algebra has been modernized, and the figures, which in the original were printed in groups on folding sheets, have been inserted separately and untouched into the text. Although some are simple definition sketches, it is noteworthy that many illustrate actual experiments with water spouting from pipes and orifices. In those more leisured days the wood-cutter could embellish a cross-section of a horizontal cannon with a dolphin on top and a fish's tail round the cascabel. Some of the title pages and tail pieces in the originals are reproduced. The title page of Daniel's book is particularly charming. In it can be discerned what seems to be a half-shrouded runner with backward blades for a centrifugal pump—a form that did not reach this country until the following century.

The volume, which concludes with a brief index of both books, will be of interest to the professional historian of science. It seems likely that the ordinary amateur of these matters will be content to dip into it occasionally and then to restore it to a position on his bookshelves where it can be noticed by visitors.

A. M. Binnie
H. J. Easterling

Thermodynamics and Fluid Mechanics Convention, 1968. Institution of Mechanical Engineers. 451 pp. £15.

This superbly printed and expensive volume comprises the 44 papers and associated discussions of the 1968 biennial convention in Bristol, arranged by the Thermodynamics and Fluid Mechanics Group of the Institution of Mechanical Engineers. About half the papers derive from University Engineering Departments, the remainder being about equally divided between research establishments of the Government (including public corporations) and industrial research departments. The topics covered are predominantly in the nature of applied rather than fundamental research and provide a good sample of the kind of problem with which the more advanced sections of the mechanical engineering industry are currently concerned. Not surprisingly, a notable proportion of the papers deal with problems arising in atomic energy plants, such as erosion due to water droplets in low-pressure steam turbines and two-phase flows. Aspects of unsteady or transient flows associated with centrifugal compressors, radial turbines and internal combustion engines also receive marked attention. There are three papers from Canada, and one from the U.S.S.R—otherwise all the papers are from U.K. establishments.

It is impossible here to summarize every paper—a few have, therefore, been selected for brief discussion to provide some further idea of the ground covered. They are not necessarily the most important, but they happen to be those that most readily aroused the interest of the reviewer.

The first paper in the book, as well as of the Convention, was a nominated lecture by Dr Shepherd of the A.E.E., Winfrith, on advanced propulsion systems in spaceflight. This provides an interesting review of the propulsive performance requirements for the more advanced missions that are now being contemplated, and the consequent need to consider energy sources other than the conventional chemical ones. Dr Shepherd concentrates on nuclear energy sources, either in the form of nuclear reactors, or radio-isotopes. He considers the basic design and performance problems involved in various suggested methods for transferring the primary energy from the source to the working fluid.

There are six papers concerned with condensation of wet steam in a turbine and consequent erosion effects and methods for their reduction. Of particular interest is a paper by Moore, Langford and Tipping of C.E.R.L., Leatherhead, describing an investigation into the size of water drops formed, their velocities of shedding from moving blades and of impact on to subsequent blades, and the development and deepening of small pits in a blade surface due to the impact. In the paper from the U.S.S.R., a method is developed by Kirillov and Yablonik, Leningrad, for calculating the condensation pressures and the trajectories of the drops, and the importance of the turbine geometry is emphasized.

Other problems involving two-phase flows are discussed in nine other papers. These include an investigation of critical conditions for gas-liquid mixtures flowing through nozzles (Chisholm, N.E.L., East Kilbride), the effect of surface cavities on nucleate boiling in water (Grant, Patten and Carrie, N.E.L., Herriot-

Watt and Edinburgh Universities), heat transfer to steam-water mixtures flowing in uniformly heated tubes in which the critical heat flux is exceeded (Bennett, Hewitt, Kearsey and Keeys, A.E.R.E., Harwell), the heat transfer on a heated circular cylinder normal to an air-water mist flow (Finlay and McMillan, N.E.L.) and the effect of air concentrations in water flow in diffusers (Young and Duggins, Nottingham University).

Inward radial flow turbines usually operate under pulse conditions and quasi-steady methods for predicting their performance characteristics are frequently found to be inadequate. Wallace and Adgey (Queen's University, Belfast) present an analysis in which they attempt to take account of the unsteady nature of the flow by considering the process of wave propagation and reflexion within the turbine passages, and for which the method of characteristics is applicable. A somewhat similar method of analysis is presented by Benson and Whitfield (U.M.I.S.T.) for pulsating flow in a centrifugal compressor, but they also present in a companion paper a quasi-steady analysis and some experimental data with which the latter method shows better agreement, The geometry of the machines considered is necessarily simplified, and losses are assumed concentrated at particular key points. These three papers evidently aroused a lively discussion.

Six papers deal with other aspects of unsteady flows. Two deal with flow in branched ducts associated with shock waves travelling past the junction (Deckker and Male, Saskatchewan University), one is concerned with flow through a poppet valve (Woods and Khan, Liverpool University), and one with flow in a pipe with a non-return disk valve (Kaddah and Wollatt U.M.I.S.T.), and two deal with aspects of flow measurement using orifices (Waters, Imrie and Cole—Leeds University, Deckker and Chang, Saskatchewan University.

The remaining papers cover a range of miscellaneous topics. In a paper by Duffy and Norbury, Liverpool University, the possibility is examined of using a pair of static pressure holes of different sizes to measure skin friction. This appears to be practicable in certain circumstances, provided there are no transverse variations of skin friction and that facilities for accurately measuring very small pressure differences are available. Cartwright and Russell, Manchester University, present some experimental measurements of velocity profiles and heat transfer for a turbulent slot jet impinging on a wall. They succeed in getting reasonable agreement with a semi-empirical theory of a conventional kind for regions away from the immediate neighbourhood of the stagnation point. The effects of a surface active contaminant (surfactant) in a fluid and the associated hydrodynamic characteristics of the surface film are considered by Kenning, Oxford University, who presents a theory and some experimental results. The theory appears adequate for dilute solutions of a single contaminant, but where there are a number of contaminants the theory is less satisfactory. Mention must also be made of an interesting paper by Rapier, A.E.A., Windscale, in which he discusses the thermal instability of a heated element in the form of a circular cylinder, or of a connected series of such elements, when cooled by convection. It is pointed out that the temperature variation round the circumference can cause distortion of the element in the form of bowing such that

greater temperature differences can result, leading to further distortion and possibly to instability. Experimental and theoretical results are presented and fair agreement is claimed.

It is presumably an intention of the organizers of the Convention that it should present the current 'state of the art' in areas of technological importance. As such the papers are in large measure of transient interest, but their value, nonetheless, should not be under-rated. Mechanical engineers at universities, as well as those engaged in the design and development of equipment for the more advanced sections of their industry, will find much that is useful in the book. For workers engaged in basic research in fluid dynamics, the value of the book is less certain, except that it is salutory for them to be made aware of both the complexity and the constraints of industrial problems. The price puts the book well outside the means of individual workers (why need it be so high?), but an interested worker need have no great qualms in persuading the librarian of his organization to obtain it.

A. D. YOUNG

Statistical Continuum Theories. By MARK J. BERAN. Interscience, 1968. 424 pp. $17.50

In recent years the development and analysis of new complicated mathematical models has been one of the main subjects of study in mechanics of continua, largely because traditional concepts have failed to describe the behaviour of many materials and media. Of first importance is the case of a medium whose micro-structure has linear dimensions which are much larger than molecular characteristic lengths. Naturally in this case it is convenient to use the methods of statistical continuum theories. In this way one may find the reasons for noted complications and moreover one may discover the required corrections to the traditional phenomenological description.

Therefore it seems useful to expound the common elements of statistical theories and to compare the different new statistical approaches with a more highly developed one such as the theory of turbulence. Thus the book by Professor Beran is to be welcomed.

Statistical Continuum Mechanics contains an attempt to show the general features of theories of different statistical physical phenomena. It starts with examples of random processes and basic ideas of probability theory and its applications to continua. Attention is paid to perturbation and variational procedures. Furthermore the author considers partial coherence, the properties of heterogeneous solid and fluid materials, fluid flow through porous media, and turbulence in fluids. I would like to discuss here the last three problems as they are connected with the mechanics of continua.

In chapter 5, devoted to the theory of heterogeneous materials, the author sets the limits for himself with the following aspects of the subject: statistical analysis of internal geometry, estimates of effective constants of mixtures of materials, for example, elastic modulus, or electrostatic permittivity. The author does not describe the ideas of generalized continuum analysis though they are

absolutely necessary for proper interpretation of the nature of motions in the heterogeneous materials.

Chapter 6 is concerned with fluid flow through porous media. The author tries to estimate the permeability of porous media on the base of some special capillary models. He considers also the statistical theory of dispersion of tracers in such a fluid flow (although without mentioning the Russian literature on this subject).

Chapter 7 of the book is a brief review of the theory of turbulence. The author considers the main ideas of the well-known theoretical investigations, including the so-called semi-empirical theories and statistical equations for moments. This review may be useful although the description is not complete. For example the author does not refer to the paper by Friedman and Keller (1922) on the derivation of the set of moment equations or to Sedov's discussion (1944) of the conditions of invariant properties of Loitsiansky's integral.

Each of the three continua being discussed by Professor Beran is a continuum with characteristic micro-structure. If one wants to use the statistical methods then it is necessary to accept some physically reasonable hypothesis about the micro-picture of the motions and to pass to macro-equations with the help of some averaging procedure. In the case of a continuum with micro-structure the micro-motions are described by equations with partial derivatives, usually by the equations for elastic solids or for viscous fluids. The author notes this circumstance on page 1 of his book, but he notes also that formal manipulation yields a set of functional equations which give little aid to the solution of problems. In my view the crux of the problem is to find the proper procedure for averaging which will lead to those quantities (stress tensor, fluxes, and so on) that can be measured and that are involved in phenomenological continuum equations.

Further development of the methods of statistical continuum theories, applicable to different branches of mechanics (fluids and solids), will undoubtedly occur in the near future. Rightly interpreted the material contained in the book can be put to good use by a discriminating reader.

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