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REVIEWS

Physics of shock waves and high-temperature hydrodynamic phenomena, volume II. By YA. B. ZEL'DOVICH and YU. P. RAIZER. (Translation edited by W. D. Hayes and R. F. Probstein.) Academic Press, 1967. 451 pp. £8 8*s*.

This volume translates the second half of Zel'dovich and Raizer's second Russian edition. (For a review of volume I, see *J. Fluid Mech.* **31**, 1968, p. 826.) Numbering of chapters and pages is consecutive with volume I, with the subject and author indexes at the end of volume II covering both volumes. The same high standards of technical accuracy and clarity of composition observed earlier characterize the six chapters included here. While the structure of subject-matter is such that volume II is directly usable by those interested in one of the particular applications covered, most active workers in high-speed or high-temperature fluid mechanics will doubtless wish to acquire both volumes of the translation.

Chapter VII, on shock-wave structure in gases, treats in succession the nature of the thin 'mechanical' shock front where viscosity dominates the scattering of directed momentum of the incident gas with conversion of kinetic energy into thermal motion, and the nature of the more complex processes of binary diffusion, relaxation, dissociation, ionization, and radient heat exchange which give shock waves their full spectrum of intriguing profiles. In the case of flows with appreciable radiation-energy content, a useful distinction is made between sub- and super-critical waves, the demarcation arising at that condition when gas upstream of the mechanical front is heated by radiation to just the final equilibrium temperature. After treating the further phenomenon of radiation-dispersed shocks (i.e. no distinct mechanical front) the text wisely stops short of an exposé of relativistic effects and shocks in the presence of magnetic fields.

Physical and chemical kinetics in hydrodynamic processes are treated straightforwardly in chapter VIII. The material is largely an extension toward selected applications of the underlying fundamentals covered in volume I. While many of the sections deal with fields that have been thoroughly ploughed before, others concern problems of significant current interest. Two of these are the sudden expansion into vacuum of gas clouds as encountered in supernovae or meteor impact on the moon, and condensation of cosmic dust. Chapter IX treats radiative phenomena associated with air shocks generated by nuclear explosions. Particularly valuable to workers in fluid mechanics is the lucid treatment of air brightness and limiting luminosity. Here, as in many places throughout the book, simple sketches and tables giving physical property data aid the understanding considerably. Chapter X, entitled 'Thermal Waves', is actually a brief treatment of the theory of heat conduction. English language readers will probably prefer to refer to Carslaw and Jaeger's book for definitive material on this special topic.

Chapter XI, on shock waves in solids, is of major significance in the total work. Occupying nearly 100 pages, this chapter gives a comprehensive treatment to the basic differences between shocks in solid media and those in gases as these affect the character of Hugoniot relations. Wave properties and phenomena arising when strong shocks emerge from solid surfaces are examined in considerable detail. The analysis is well selected to cover a range of effects observed during twenty years of vigorous Russian experimentation at pressures up to 5 million atmospheres. This pressure is sufficient to produce a doubling in density of many materials, and so has opened the whole new field of condensed matter for study. This chapter concludes with discussions of the luminosity of metallic vapours generated in shock unloading, and measurements of the electrical conductivity and index of refraction of non-metals under high compression.

The final chapter of the book reaches back into the preceding material for a systematic treatment of self-similar processes in gas dynamics. Centred rarefactions, strong explosions, and heat conduction in a uniform medium are familiar examples. Applications of geophysical interest in which significant new results are reported are the analysis of explosions in porous media and in an inhomogeneous atmosphere with an exponential density distribution.

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Fluidized Particles. By J. F. DAVIDSON and D. HARRISON. Cambridge University Press, 1963. 155 pp. 35*s*. or $6.50.

The complicated motions of solid particles and fluid in the fluidized catalytic reactors now used so widely in the petroleum industry have long been recognized as holding the key to understanding their behaviour and their logically correct design. Most of the early experiments established only a few facts about the suspension of finely divided solids in the rising current of fluid: that the fluid pressure difference needed to support, i.e. to 'fluidize', a bed of solid particles equals the buoyant weight of the solid particles; and that only a small fraction of the total gas flow goes through the interstices between particles, most of the gas forming pockets or 'bubbles' which contain very few suspended particles. It has been considered unlikely that fluid reactants in these bubbles could react with the solids completely, even though there is obviously no interfacial barrier separating fluid inside the bubbles from that flowing between the particles, and fluid may very well flow in and out of the bubbles. Without a knowledge of fluid velocities between the particles, particularly at the boundaries of rising bubbles, there has been no way to estimate the exchange of fluid between the phases.

Some of the most revealing studies of fluid motion in these complicated situations have been made at Cambridge University by J. F. Davidson, D. Harrison and several of their students. *Fluidized Particles* is a short but complete account of the results obtained and an analysis of their use for the design of chemical reactors. It is unusual to find an account of a coherent and continuing investigation of an industrially important subject coming from a university laboratory. The book is primarily a discussion of the authors' point of view; it does not offer a general, encyclopedic coverage of all the published information. Although others working in the field may disagree with the authors on details, anyone undertaking such studies in the future will find it essential to understand the Cambridge work fully; it will very likely be the point of departure for future improvements.

The flow analysis described in the book depends on the unexpected experimental observation that the bubbles rise through the suspended particles at a velocity which agrees closely with values expected from a formula due to R. M. Davies and G. I. Taylor (*Proc. Roy. Soc.* A, vol. 200, 1950, p. 375) for the rising velocities of large gas bubbles in liquids. The implication is that the motion of solid particles around the gas cavities is that of a potential flow of an ideal fluid. Adding to this the assumptions that the density of particles in the particulate phase around the cavities is nearly constant and that the slip of fluid past the particles is given by Darcy's law, Davidson and Harrison have been able to calculate the rates of gas leakage into and from each rising bubble. The leakage rate is the key to estimating the catalytic reaction rate in the apparatus. Experimental evidence from reaction rate studies lends support to the conclusions.

Some things remain not quite clear about these bubble phenomena: how do the bubbles originate; do they grow in volume as they rise; if so, do they grow by infusion of fluid from the particulate phase or by coalescence; and how large can they become before they split into fragments? The authors have had to make somewhat arbitrary but plausible assumptions to deal with such questions. Future studies can be expected to yield more complete answers but not to change substantially the point of view introduced in this very fine book.

Fluidized Particles is not intended as a text on fluid mechanics for general use. Although it contains information on bubble behaviour in liquids, the principal subjects are the behaviour of bubbles in fluidized beds, the rates of exchange of gas between bubbles and the surrounding phase of suspended solids, the stability of bubbles, and the influence of bubbles on the use of a fluidized bed for catalysing chemical reactions. Such subjects are of great interest in chemical engineering instruction for supplementary study of important applications of fluid mechanical theory.

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