

## REVIEWS

**Aerodynamic Phenomena in Stellar Atmospheres.** Edited by R. N. THOMAS. Bologna: Nicola Zanichelli, 1961. 515 pp.

This volume is the edited report of the proceedings of the Fourth Symposium on Cosmical Gas Dynamics, sponsored jointly by the International Astronomical Union and the International Union of Theoretical and Applied Mechanics, and held at the Fermi International School of Physics at Varenna in August 1960. This co-operation between astronomers and aerodynamicists began when J. H. Oort of Leyden Observatory wrote to J. M. Burgers about the theoretical problems posed by the spectroscopic discovery of interstellar gas clouds with their highly supersonic random velocities—‘compressible turbulence’. There followed, at 4-yearly intervals, three Symposia on the gas dynamics of cosmic clouds, with the emphasis changing from the initial enthusiastic and rather uncritical extrapolation of laboratory fluid dynamics, to a more cautious approach, combining experience gained in the laboratory with detailed study of the relevant microscopic physics. Meanwhile, there had been an enormous increase in detailed observations of stellar atmospheres and an associated refinement in interpretative theory, and the time was ripe to interest aerodynamicists in the analysis of the inferred velocity fields.

It had been known for many years that the widths of Fraunhofer lines are inconsistent with the purely thermal Doppler broadening predicted by the orthodox theory of spectral line formation. Many workers have claimed that the single postulate of a local random subsonic velocity field, of a scale small compared with a photon mean-free-path—‘microturbulence’—is sufficient to remove all discrepancies. In addition, the name ‘macroturbulence’ has been coined to cover all the irregular large-scale motions in the atmospheres of the brightest stars, inferred not from line strengths but rather from line shifts and from changes in profiles. An excellent review of the relevant astronomical data is given by Miss A. Underhill.

Aerodynamics enters the spectroscopic problem when we consider the coupling between the thermal and velocity fields, both through the contribution of the normal Reynolds stress to momentum balance, and the departure from radiative equilibrium due to the dissipation of the velocity fields. The orthodox view, expressed in the Symposium by A. Unsöld, is that these feed-back effects are small in the regions where the Fraunhofer lines are formed, so that both the inferred micro-turbulent velocities and the estimated element abundances are reliable. The sceptical view, put forward by R. N. Thomas and J. C. Pecker, is especially critical of the assumptions of local thermodynamic equilibrium and of purely radiative energy transfer. Higher up in the solar atmosphere, where there is ample independent evidence for an outward temperature *increase* to a coronal maximum of about  $10^6$  °K, the energy source due to aerodynamic dissipation is all-important. But according to the critics, the Unsöld-type analysis applied in this region fails to predict a large random velocity field: the

analysis does not include an automatic check on its region of validity. Without placing the onus of proof on one side rather than the other, one cannot but agree with Thomas, that 'there is little point in constructing aerodynamic theories to explain an inferred velocity field, until one is sure that the existence of such a velocity field is consistent with the basis upon which is derived the theory used to infer the velocity field'.

However, since the postulated microturbulence is subsonic (though of Mach number possibly as high as  $1/3$ ), the aerodynamicists at the Symposium were not particularly surprised at its presence, nor did they feel concerned in the squabble between the astrophysicists as to how much of it is a spurious consequence of approximations in the theory of line formation. Further, the introductory lectures to the remaining sessions intentionally deflected attention from this controversy, and also from the problems of macro-turbulence raised by Miss Underhill, to problems with a rather less exacting standard of observational verification. The longest section is devoted to spherically symmetric laminar motions in stellar atmospheres, beginning with a review by P. Ledoux and C. A. Whitney on pulsating variable stars. Before considering the atmospheric problems, they present (in response to requests from the audience) the classical (Eddington) theory of linear, nearly adiabatic, spherical oscillations of the whole star, with the small departures from adiabacy determining whether an initial small oscillation is damped, or is steadily built up to a finite amplitude. Recent work by S. A. Zhevakin suggests that the zone of second helium ionization may provide the necessary 'negative dissipation' in stars within a narrow parameter range. In the absence of a sharp boundary, the oscillation penetrates into the atmosphere as a progressive wave which steepens into a shock as it reaches lower densities, so distorting the observed light and velocity curves, and providing extra dissipation. In the next report, E. Schatzman takes up the problem of shock propagation in atmospheres of varying density. Dissipation of waves generated in the subphotospheric convection zone is almost certainly responsible for the heating of the chromosphere and the corona, though there is argument as to whether the waves are mainly sound waves or magneto-hydrodynamic compression waves. The rest of this section deals with non-catastrophic mass-loss—essentially the reverse of the gravitational accretion problem. A. J. Deutsch emphasizes flow with velocities well below the escape velocity, as suggested by his observations of *M*-type giants, and E. N. Parker the high-speed 'solar-wind' flow. P. Germain presents the mathematical theory that includes both cases.

The last section, on localized velocity fields, begins with reports on observations of the granulation of the solar surface, after which Frau Böhm-Vitense surveys the 'mixing-length' theory of the solar convection zone, inevitably arousing strong criticism from the aerodynamicists. W. V. R. Malkus and E. A. Spiegel describe different attempts at deductive theories of turbulent convection. A correct theory is required not only for comparison with the observed granulation, but also to remove an uncomfortable uncertainty in the boundary condition to be used in the theory of stellar structure. A. B. Severny describes velocity fields in the lower solar atmosphere—the Evershed flow near sunspots,

and the motions in flares and prominences. The ensuing discussion touches on many topics in solar hydromagnetics. Finally, H. E. Petschek, and A. A. Blank and H. Grad provide a link with the frontiers of plasma physics in their qualitative discussions of shocks in collision-free plasmas, relevant because of the long mean-free-path in the corona.

The volume makes very satisfactory reading, partly because of the policy of having a few review lectures plus discussion, rather than a plethora of original papers, and also because of very skilful editing. The discussions are clear, and there are excellent concluding summaries by H. Liepmann, R. N. Thomas and R. Lüst. It is to be hoped that more fluid dynamicists and plasma physicists will be induced to wander into astrophysics, where they will surely find a lifetime's work.

L. MESTEL

**Advances in Applied Mechanics, Vol. VII.** New York: Academic Press, 1962. 327 pp. £4 8s.

(Papers on fluid mechanics:

‘Hypersonic flow over slender bodies associated with power-law shocks’, by H. Mirels and

‘Some elementary problems in magnetohydrodynamics’, by R. Hide and P. H. Roberts.)

**Reports on Progress in Physics, Vol. XXV.** The Institute of Physics and the Physical Society, 1962. 529 pp. £4 4s.

(Papers on fluid mechanics:

‘Magnetohydrodynamics’, by T. G. Cowling and

‘Shock waves in gases’, by H. J. Pain and E. W. E. Rogers.)

Of the four papers under review, the last two are surveys of their respective fields, whereas the first two deal with special, particular problems. Hide and Roberts do in effect provide a partial survey of their field through a study of various easy cases. The Hide–Roberts paper is some 100 pages long and almost constitutes a small text-book. The authors state their objective is the praiseworthy one ‘to provide an introduction to hydromagnetics in which the physical wood is not obscured by mathematical trees’. The paper must therefore be judged against its own high aspirations.

It is natural to discuss the two papers on magnetohydrodynamics (MHD) together. Both papers endeavour to present a balanced view of MHD, but the authors fail to conceal their astrophysical or geophysical backgrounds. Both papers contain several stimulating remarks that add to one's appreciation of MHD, what its place in science is, how it developed and how it ‘works’. I liked particularly the remarks of Hide and Roberts (*à propos* of the fact that true MHD was not discovered in the laboratory): ‘One wonders how ordinary fluid dynamics would have developed had no fluid less viscous than thick treacle been available to the experimenter.’ I also liked the directness of Cowling, discussing an encounter between a highly conducting stream and a magnetic

field: 'If the magnetic pressure were large, the plasma would be reflected by the field; if small, the plasma would bore a hole through it.' This evocative, imaginative level is regrettably not sustained; the later parts of the Hide-Roberts paper dwell on various linear or linearized problems, trivial mathematically and not handled so as to be physically illuminating. At various points the authors rather bewilderingly veer off the main course (of expounding general MHD ideas) to concentrate on special problems, obviously close to their particular hearts.

Hide and Roberts cover the following main topics: the MHD approximation and its validity; boundary conditions; plane waves and shocks; gravity waves and instabilities; a selection of simple one-dimensional linear problems concerning Alfvén waves and Hartmann flows between parallel walls; and finally energetics and relativity, discussed in two appendices. The section on boundary conditions is noteworthy for its thoroughness and the fact that it includes the Hartmann boundary condition at a fluid-solid interface in the limit of the inviscid, perfect conductor. This is not as widely known as it should be.

Cowling's paper is shorter but valiantly attempts to cover more ground. Where Hide and Roberts solve their problems completely, Cowling often has space only to mention authors and their results, together with all-too-brief comments. There is hardly any mathematical detail. Editors who invite review articles on MHD should ponder the sheer size of the subject, which includes ordinary fluid mechanics as a degenerate case. Just as nobody would be expected to write a review article on fluid mechanics as a whole nowadays, unless a very superficial result were wanted, even more should nobody be expected to cover more than a fraction of MHD in one short article. After only ten years of widespread activity in MHD, *homo sapiens* has produced on average at least one paper a day on the subject in the published literature!

Some unity is given to Cowling's treatment by the use of the concept of the virtual velocity of field lines,  $\mathbf{E} \times \mathbf{B}/B^2$ , although the pitfalls of this concept are not mentioned. After an introduction he presents a section on liquid MHD, including Hartmann flow, various instabilities and the experiments of the Stockholm group. His next section deals with plasmas and the occurrence of the Hall effect, pressure anisotropy, etc., whenever collisions become relatively rare. He continues with glimpses of magneto-acoustics, MHD shocks and the problems of controlled fusion and direct generation from fusion and combustion plasmas. The final section is pure astrophysics and geophysics.

We turn next to the admirable Pain-Rogers compilation, sensibly divided into an aerodynamic part and a physical part. Most aspects of shocks are mentioned, even the cracking of whips! Much of the paper is thorough and explicit, but—as in most review articles—there is a tendency to resort to name-dropping, i.e. mere listing of authors of papers, towards the end of the paper and of its sections.

The aerodynamic part confines itself to perfect gases with constant specific heats. There is a useful survey of plane, spherical and cylindrical shocks and of reflection and diffraction phenomena. A nice blend of theory and experiment is maintained. The appraisal of difficult problems like Mach reflection and, later,

shock-boundary layer interaction is particularly to be welcomed. There is also a capable survey of the shock structure problem, with a comparison between continuum theory, kinetic theory and experiment.

The effect on shock structure of relaxation processes and chemical kinetics is discussed in the second, physical part of the paper. Later the authors discuss the problem of shock structure in ionized gases of low Prandtl number, with and without magnetic fields. They also review some of the theories for collision-free shocks. This is my cue to complain about the many different meanings attached to the word 'adiabatic', which classical thermodynamicists interpret as 'devoid of heat transfer', some physicists as 'isentropic' and plasma physicists as 'collision-free' in various sophisticated senses, so that confusion reigns.

The physical section also contains brief descriptions of pressure-driven shock tubes and some types of magnetic shock tubes and of experiments on shock-ionized gas, including encounters with magnetic fields. This paper is an excellent guide to the literature, particularly on aerodynamic aspects and on shock structure. It is potentially very useful for initiating research students.

Finally we have the Mirels paper, which is confined to a much narrower field than are the others under review. It is a very homogeneous amalgam of the work of many authors, notably Mirels himself, and presents a thorough and detailed exposition of its theme. It is so specialized that little comment is called for here, though it will be welcomed by the hypersonic-theory fraternity, who should observe that there is an addendum to the paper at the end of the volume. Some of the work has already been published by Mirels in N.A.S.A. reports. I cannot help wondering what useful purpose is served by lumping together in one volume (*Advances in Applied Mechanics*) such a diverse set of monographs. Besides the unrelated ones by Mirels and by Hide and Roberts, this volume contains ones on brittle fracture and plasticity. Separate publication of at least the longer articles would be much more sensible, particularly if at the same time the unwholesome effects of over-compression could be avoided.

J. A. SHERCLIFF

**Mécanique Expérimentale des Fluides.** By R. COMOLET. Paris: Masson et Cie. Vol. I, 1961, 244 pp., 38 NF. Vol. II, 1963, 442 pp., 72 NF.

In the history of the mechanics of fluids, one country after another has come periodically to the fore, usually with a fresh approach to the subject as well as a burst of productivity. France is surely no exception to this intermittent process; in fact, not only did her engineers and scientists hold a position of leadership for at least a century, but even the name of the subject was coined by one of them. At no time, however, have text-books as such played the role in France that they have in other—particularly the English-speaking—countries. Lecture notes for course use, to be sure, were frequently lithographed from handwritten and typewritten copy, and some of these eventually reached letter-press form. Nevertheless, the French publishing world has only recently begun to reflect the general text-book trend. The two volumes by Professor Comolet, of

the Faculty of Sciences first at Nancy and now at Paris, represent a case in point.

The first, and smaller, volume, with the title *Statics and Dynamics of Inviscid Fluids*, contains nine chapters on the following topics: generalities, statics of fluids; kinematics of fluids; dynamics of perfect fluids; applications of the Bernoulli theorem; applications of the momentum theorem; dynamics of compressible fluids; one-dimensional flow of a perfect gas without friction; shock waves; propagation of elastic waves, water hammer. The second volume is divided into two parts, of which the first, under the title *Dynamics of Real Fluids*, contains ten chapters: viscosity, movement of a viscous fluid; laminar flows; turbulent flows; theory of models; theory of the boundary layer; aerodynamics of geometrically simple bodies; airfoils; flow in conduits; flow at conduit transitions; flow in open channels. The second part, entitled *Theory of Turbomachines*, embodies another seven chapters: generalities of turbomachinery; hydraulic turbines; turbo-pumps and blowers; hydraulic transmissions; compressible-fluid machines; turbo-compressors; steam and gas turbines. The two volumes together contain more than 550 line drawings, and the second ends with 16 plates of beautifully printed photographs, largely French, ranging from flow patterns to turbine runners.

From the chapter headings it is evident that the book is of the class that caters primarily to students in civil and mechanical engineering. In paging through it one is impressed by its breadth of coverage and the amount of detail that has been assembled. However, rather than the fresh approach that would indicate a new school coming to the fore, one encounters familiar presentations from the English, German and American text-book literature comprising the major part of the author's bibliography. He surely reflects the French point of view, and the selection and arrangement of material are clearly his (with the influence, perhaps, of his acknowledged mentor, Professor A. Fortier of the Sorbonne), but otherwise there is little new or original to make the work stand out. The figures, in fact, are sometimes overly reminiscent of those in other works, and certain of the graphical inconsistencies have appeared in the literature for many a generation: imperfect flow nets, streamlines that break or divide impossibly, premature occurrence of separation, diffusion sketched as unilateral, or free-surface profiles that fail to follow the very principles that are being propounded. These are obviously not major issues, but they do point to knowledge that has been acquired in the library rather than from first-hand experience in the laboratory or field.

If one also overlooks such misconceptions as the inclusion of pressure among the various forms of energy, and the frequent tendency to appear to generalize yet actually to treat a matter superficially, one must grant that the author has touched upon many an aspect of fluid motion and presented the standard principles in a very inclusive manner. What began as the relatively modest undertaking evidenced in the first and more analytical volume apparently grew to several times its anticipated size as the vast assortment of experimental findings from the world's laboratories was assembled for the second. Obviously difficult for even a teacher to master, assimilation of the material that the author

covers should prove a remote goal toward which his students can only strive. All in all, the book will probably find greater favour in France than in countries where the text-book competition is already keen.

HUNTER ROUSE

**Proceedings of the 1963 Heat Transfer and Fluid Mechanics Institute.**

Edited by A. ROSHKO, B. STURTEVANT and D. R. BARTZ. Stanford University Press, 1963. 288 pp. 70s.