REVIEWS

Handbook of Supersonic Aerodynamics. Published by Bureau of Naval Weapons, U.S. Navy, and for sale by U.S. Government Printing Office, Washington D.C.

Eleven sections of this *Handbook* have been published so far, the first appearing in 1950, and ten more are to be published eventually. All the editorial work has been done by a group at the Applied Physics Laboratory, Johns Hopkins University. According to the Preface: 'The primary criterion used in selecting material for the *Handbook* is its expected usefulness to designers of supersonic vehicles. Thus a collection of data directly useful in the design of supersonic vehicles, results of the more significant experiments, and outlines of basic theory are included at the risk of producing a handbook that may be considered somewhat unconventional and heterogeneous in content'.

The sections of the book, either already published or to be published in the future, are as follows:

Section			Year of publication
	Volume 1		
1	Symbols and Nomenclature. 21 pp.	$1.75	1950
2	Fundamental Equations and Formulae. 35 pp.		
3	General Atmospheric Data. 123 pp.		
4	Mechanics and Thermodynamics of Steady One-Dimensional Gas Flow. 155 pp.		
	Volume 2		
5	Compressible Flow Tables and Graphs. 188 pp.	$1.50	1953
	Volume 3		
6	Two-Dimensional Airfoils. 85 pp.	$1.50	1957
7	Three-Dimensional Airfoils. 67 pp.	$1.50	1958
8	Bodies of Revolution, by D. Adamson	—	Future
	Volume 4		
9	Mutual Interference Phenomena, by Cornell Aeronautical Laboratory	—	Future
10	Stability and Control Analysis Techniques, by R. S. Swanson	—	Future
11	Stability and Control Parameters, by R. S. Swanson	—	Future
12	Aeroelastic Phenomena. 107 pp.	$1.25	1952
	Volume 5		
13	Viscosity Effects, by R. E. Wilson	—	Future
14	Heat Transfer Effects, by R. E. Wilson	—	Future
15	Properties of Gases. 228 pp.	$2.00	1953
16	Mechanics of Rarified Gases, by S. A. Schaaf and L. Talbot. 75 pp.	$1.25	1959

Section	Volume 6		Year of publication
17	Ducts, Nozzles, and Diffusers, by C. L. Dailey	—	Future
18	Shock Tubes, by I. I. Glass and J. G. Hall. 598 pp.	$3.75	1959
19	Wind Tunnel Design, by A. Pope	—	Future
20	Wind Tunnel Instrumentation and Operation, by R. J. Volluz	—	Future
21	Ballistic Ranges	—	Future

Sections 6, 7 and 12 were prepared at the Applied Physics Laboratory, Johns Hopkins University; section 5 at the Ordnance Aerophysics Laboratory, Consolidated Vultee Aircraft Corporation; and section 15 by staff at both these laboratories, working in collaboration.

A large part of the *Handbook* is made up of tables and graphs, with only an outline of the relevant theory. This arrangement is appropriate for a handbook intended primarily for designers, as this one is, but as with all handbooks there are disadvantages as well as advantages. Those who already have a good understanding of the fundamentals of supersonic flow will undoubtedly find it useful, but the inexperienced user of the book may find that he is tempted to make use of theoretical results without understanding clearly the limitations imposed by the assumptions on which they are based. Some attempts are made to deal with this difficulty; for example in section 7, which is based entirely on the linearized equation of motion for an inviscid gas, a few pages at the end are devoted to comparison of some experimental and theoretical results.

In section 2 there is a condensed account of the equations of motion and basic thermodynamics. The usual expressions are derived for one-dimensional steady isentropic flow, Prandtl-Meyer flow, and flow through plane shock waves. Corresponding numerical tables are given in section 5, for $\gamma = 9/7, 7/5$ and $5/3$.

Section 3 is very comprehensive, but as it was published in 1950 the data for the upper atmosphere are now out of date.

Section 4 consists of a verbatim reprint of a paper by A. H. Shapiro and W. R. Hawthorne (*J. Appl. Mech.* **14**, 1947, A–317), together with numerical tables issued by the same authors with G. M. Edelman in 1947.

In section 6, on two-dimensional aerofoils, there are numerous graphs giving results of calculations by first-, second- and third-order theories and by the shock-expansion method. Some comparisons with experimental results are also given.

Section 7, dealing with three-dimensional aerofoils, and based on the linearized equation of motion, is comparatively brief in relation to the magnitude and practical importance of the subject, being no longer than section 6.

Section 12 is a collection of data for use in flutter calculations. The approximations made in computing the coefficients are not made very clear and some users of the book may perhaps be misled by the large number of significant figures given in the tables.

Despite its title, section 15 deals only with the properties of *air*, and in particular with departures from the perfect gas laws and effects of dissociation at high temperatures. Tables are given for dry air and also for air with various amounts of moisture. Effects of non-zero relaxation times are not considered. The tables are based on the ones compiled by Hirschfelder and Curtis in 1948 and on the NBS-NACA tables issued in 1949 and later years.

In section 16 some results are given for a *perfect gas* in slip flow and in free-molecule flow.

In section 18 the declared object of the *Handbook* has apparently been set aside temporarily, for there is little here that is likely to be useful to a 'designer of a supersonic vehicle'. This section, unlike the others, is directed more to the research worker than to the designer. It is very long and the index is poor, so that although there is much useful information a particular item cannot easily be found. For example, a prolonged search was needed in order to find the equation relating the pressure ratio across a diaphragm to the strength of the shock wave that is formed in a shock tube; moreover this equation, which is of fundamental importance, does not appear until page 65. In contrast to this, imperfect gas effects are introduced as early as page 35, which makes difficulties for a reader who is new to the subject. In the chapter on instrumentation (75 pages) the measurement of force components on a model seems to have been overlooked.

With the exception of section 18, the whole of the *Handbook* should be useful to designers. Some of the sections, notably, 2, 4, 5, 15, 16 and 18, should also be useful to research workers. It is unfortunate that some of the indexes are poor, since the book is intended more for quick reference than for prolonged study.

Most of the sections can be purchased individually, at fairly low prices. Those who frequently have to make calculations in supersonic aerodynamics are likely to find some of them useful.

W. A. MAIR

Hydromagnetic Channel Flows. By LAWSON P. HARRIS. M.I.T. Technology Press, 1960. 90 pp. 22*s*. or $2.75.

Wanted: Strong lad, willing and able to perform experiments on the turbulent flow of liquid metals in transverse magnetic fields.

This appeal is inspired by reading the volume under review along with several other theoretical or speculative treatments of the problem. The only experimental observations available to relate these various discussions to reality are the very early ones of Hartmann and Lazarus and those made by Murgatroyd ten years ago. Both were exploratory investigations with features now open to criticism; the results could certainly be improved upon; and yet they have been treated as holy writ by the many empirico-theoreticians who have considered turbulent magnetohydrodynamic flow, building elaborate analyses on this very limited experimental foundation. The pressing need is for fresh experimentation which would repeat the pressure gradient measurements of the earlier workers and also go further and investigate the mean and eddying velocity distributions. Then it will be appropriate for some would-be Copernicus from the many to extract order from the established facts.

In his book Harris remarks that the results of Hartmann and Lazarus cannot be taken as particularly reliable. With only two pressure tappings to establish the pressure gradients, errors could easily arise owing to defects of the tappings. The pipes were so small as to be somewhat uncertain in size and shape, and, as Hartmann was aware, the pressure drops included small contributions due to the current loops at the edges of the magnetic field. In addition, they would include small contributions associated with the adjustment of the velocity profile in the magnetic field.

Murgatroyd used several tappings and deduced his pressure gradients from readings in the region away from the edges of the field, where the pressure fell in reasonably linear fashion. However, the edge current loops still exert a baleful influence here because of their tendency to create vorticity at the edge of the field. As a result the velocity profile is deformed. To be completely satisfactory any new experiments would need to eliminate this complication by the use of streamwise baffles or deliberately broadened fringes at the edges of the field. This distortion of the profile is most pronounced at the higher field strengths and lower flow rates, where laminar flow tends to occur. Thus it may be that Murgatroyd's results for turbulent flow do not suffer on this account. His magnet only permitted a relatively short length of apparently fully developed flow, and any new experiments should employ magnets with pole-faces long enough for it to be certain that a steady state of flow was reached. This is particularly necessary where critical Reynolds numbers for transition to or from turbulence are concerned.

Harris's discussion and analysis of the experimental results is sensible and his assumptions plausible. The book is actually a reproduction of an unusually lucid and mature Ph.D. thesis. The approach adopted is a generalization of the derivation of the universal velocity distribution in ordinary channel flow, using the ideas that the flow near the wall is independent of channel size while the velocity defect away from the wall is independent of viscosity, there being a substantial region where both ideas apply. Harris argues sensibly that the effect of induced fields may be neglected so that only the Hartmann number M and the Reynolds number R govern the problem. His analysis leads to a formula for the friction factor f in terms of two unknown functions, one of which he discards for not wholly convincing reasons. However, the available experimental results do correlate quite well under the scheme thus developed, which states that, for a given pressure gradient, $f^{-\frac{1}{2}}$ (which is proportional to flow rate) differs from its value in the absence of magnetic field by a function of M^2/R^*, R^* being the Reynolds number based on friction velocity. At low values of M^2/R^* the flow is increased slightly and at high values it decreases markedly. In the first case the damping of turbulence is dominant, while in the second the deformation of the mean velocity profile produces high rates of shear near the walls. Harris goes on to deduce further consequences of his theory such as the distributions of velocity and Reynolds stress across the channel. The theoretical analysis is probably more sophisticated than the experimental information warrants, but the ideas presented are undoubtedly stimulating, particularly in indicating what details should be scrutinized in further experiments.

A typical case in point is the conclusion that when the magnetic field is nearly but not quite strong enough to suppress the turbulence completely, it restricts it to the boundary layers, the central motion being at a uniform steady velocity. This should be readily observable by the use of probes to detect fluctuating induced voltages. Going further than Harris, one can argue that when this broad central laminar region occurs, the channel width ceases to affect the boundary layers, the representative length scale controlling them now being the Hartmann laminar boundary layer e-folding length. A simple-minded proposal is then to use the universal friction factor formula of ordinary channel flow with the channel width replaced by the Hartmann length and with numerical coefficients chosen to suit Murgatroyd's results for the régime in question. The resultant formula

$$f^{-\frac{1}{2}} = 6\log_{10}(R^*/M) - 1{\cdot}6,$$

accounts adequately for those of Murgatroyd's results for which f depends only on R/M or R^*/M until M gets too small and the turbulence too strong. Note that $R = 4R^*(8/f)^{\frac{1}{2}}$ here. Rough limits on the region where the formula appears to hold are $2000M > R > 900M$, where the lower limit is the one given by Murgatroyd for complete suppression of turbulence. It is not surprising that this suppression should occur at a fixed value of R/M if by then the channel width is irrelevant. The quantity f may still be a function only of R/M when $2000M > R$ as Murgatroyd observed, provided R is large enough, but the form of relation given above ceases to apply.

Harris's correlation in terms of M^2/R^*, a quantity which depends on channel size but is independent of viscosity, is more appropriate to the case of vigorous turbulence which spans the channel.

In this review I have concentrated on those aspects of the book that are of general fluid-dynamical interest, leaving aside the technologically important later chapters which deal theoretically with laminar and turbulent flow in a.c. induction pumps. In discussions of skin friction in pumps and other situations where there is current flow to and from the liquid, in contrast to the Murgatroyd case, it must be remembered that the pressure gradient no longer simply defines the skin friction.

To conclude, this is a stimulating book which deserves close study by all who are interested in magnetohydrodynamic channel flow and particularly by those who are proposing, or who can be induced, to undertake further experiments.

J. A. Shercliff