REVIEWS

Shock Tubes. By J. K. Wright. London: Methuen, 1961. 164 pp. 13*s*. 6*d*.

The Shock Tube in High-temperature Chemical Physics. By A. G. Gaydon and I. R. Hurle. London: Chapman and Hall, 1963. 307 pp. 65*s*.

Although the principle of the shock tube was described by Vieille towards the end of the last century, the development of the shock tube as a research tool only took place many years later following the systematic researches of Payman and Shepherd. During World War II, shock tubes were used mainly to investigate the physical behaviour of shock waves under conditions of unsteady flow; the contributions of the physicist groups at Princeton and Ann Arbor were specially noteworthy during this period. Since then shock tube techniques have become common in a wide range of fields of research, particularly in the study of strong shocks propagated through plasmas, in gas-dynamical investigations of hypersonic flow conditions and in problems relating to chemical reaction kinetics.

The initial sections of the volume by Wright (one of the well-known Methuen's monographs on physical subjects) are devoted to a brief outline of the dynamical principles for both ideal and real gases. This is followed by an outline of how a shock tube works. There follows then an account of the several optical, electronic and radar techniques that have been developed to measure gas density, pressure, wave velocity, and so on.

The subsequent two chapters relate more properly to the subject of gas dynamics rather than shock tubes as such. The first of these chapters describe the reflexion, refraction and diffraction properties of shock waves, topics which were first investigated by shock-tube techniques by the American groups referred to above, and the second gives an account of shock-wave structure in real, as distinct from ideal, gases. Several of the original papers referred to in these chapters are unpublished war-time American reports and are therefore not available generally.

The two concluding chapters deal with the means of production of strong shock waves, such as the electromagnetically driven T-tube, and with some of the varied investigations that have been carried out with such equipment. The volume closes with a brief series of notes on relatively recent shock-tube investigations in fields such as thermonuclear research, magnetohydrodynamic interactions and the like.

In writing this volume, the author has followed the traditional development of his subject; thus the treatment is mainly aimed at outlining the methods of investigating unsteady phenomena and there is only brief mention of the recent developments of shock-tube techniques for the study of steady-flow conditions in the hypersonic regime. The development of 'hot shot' and light gas gun tunnels for the investigation of hypersonic flows is not touched on.

Within its limited scope, Wright's monograph gives an adequate and useful outline of the general development of shock-tube techniques, with some description of individual investigations. The bibliography lists some 130 references, which should be adequate initially for anyone wishing to explore a particular type of application. However, the subject is still growing rapidly, and abstracting journals record some twenty-five to thirty new papers each year, excluding a greater number of papers that deal with particular applications.

The book by Gaydon and Hurle is considerably longer and sets out specifically to present a unified account of shock-tube research into chemical and physical processes at high temperatures, especially in the range 1000–5000 °K. The main emphasis is on experimental methods and results, although the first few chapters have considerable theoretical content in that they describe the basic properties of shock waves in both ideal and real gases in considerably more detail than was possible in Wright's small book.

There follows a chapter describing the various types of gas flow and wave systems that are observable in shock tubes. In the next four chapters the authors discuss extensively matters relating to shock-tube design and the techniques available for the detailed measurement of velocity, pressure, density and temperature. The last four chapters are devoted to a fairly detailed survey of the chemical and physical-chemical aspects of shock-tube research; the authors are authorities on these matters and provide a very readable account of various topics. Thus, after a discussion of relaxation processes and the measurement of relaxation times, the authors outline the scope of the shock tube for a variety of chemical investigations; they then discuss the recording and interpretation of emission and absorption spectra. They conclude with a discussion of gaseous detonation phenomena that are shock ignited.

Although the volume by Gaydon and Hurle is mainly concerned with the application of shock tubes to an understanding of problems in chemical physics, their work should prove valuable to members of other disciplines who desire to understand some of the many intricasies of shock-tube research. In particular it should help to bridge the gap between continuum and molecular concepts of the phenomena being investigated. The work contains a very useful bibliography of about 330 references.

J. W. MACCOLL

Real Gases. By A. B. CAMBEL, D. P. DUCLOS and T. P. ANDERSON. Academic Press, 1963. 166 pp. $6.50 or 52*s*.

This monograph is the first of an international series on engineering physics launched by the publisher. The target is presumably composed of engineers who have come face to face with practical problems for which solutions based on the classical concepts of an ideal gas are inadequate. The authors strike a fair balance between two extremes which have handicapped some of the earlier engineer's guides to modern science. They neither take the view that 'this subject is very mysterious and you must study it for years', nor do they say, 'this subject is really very simple and here is the formula'.

The main body of the text is intelligently written for an intelligent audience. The title, *Real Gases*, and the descriptions in both the preface and introduction of what is being talked about are, however, most unfortunate. An ideal gas is commonly defined as having the equation of state $p = \rho RT$, constant specific heat, and, for fluid mechanical purposes, zero viscosity. These conditions are satisfied to any desired degree in a number of situations. It is ironic that the authors go to some trouble to exclude from their definition of real gases the large and very important number of cases for which these conditions do in fact hold true. The matter of constant or variable specific heat isn't even brought up in the introductory remarks. After this somewhat cumbersome start, however, the text reads well.

Aerodynamic and thermodynamic implications of the physical processes of intermolecular attraction, excitation, reaction, and ionization constitute the main subject matter. Each phenomenon is described with care in order to give the reader a clear physical understanding. Relevant equations are presented and their realm of applicability discussed at some length to preclude or at least to reduce the chance of blind misapplication. In general formulas are not derived in sequential order unless this can be accomplished with an ease and simplicity appropriate to the spirit of a small monograph.

Milestones indicating progress along the route chosen include the fundamental conservation equations of fluid mechanics, equations of state, the partition function, the Law of Mass Action and Saha's Equation, the Debye–Huckel theory for ionized gases, high density effects, and recombination processes. As one progresses into the more complex aspects of reacting and radiating fluids, the clarity and completeness observed earlier begins to wane and the book closes with a note of remorse: 'This seems to verify the existence of different recombination mechanisms at different pressures, seriously complicating theoretical approaches to the problem'.

WAYLAND C. GRIFFITH

Combustion and Propulsion: Fourth Agard Colloquium. Edited by A. L. JAUMOTTE, A. H. LEFEBVRE and A. M. ROTHROCK. Pergamon Press, 1961. 396 pp. $15.00.

This book contains material of two distinct types presented at an AGARD colloquium at Milan in 1960 on high Mach number air-breathing engines. Parts I, II, III and VI present analyses and experimental results on engine system or engine component performance. The remaining three parts, IV, V, VII, are devoted to discussions of some of the fundamental gas dynamics and materials problems of importance to air-breathing engines. In pages, the book divides about evenly between the two general topics.

The parts of engine application interest begin with a discussion of 'The Future of Air-Breathing Engines'. Here, as always, present ideas and performance are stretched to the ultimate and dreams are analyzed as concisely as time and technology permit.

Part II on 'Hypersonic Ramjets' and Part III on 'Hypersonic Inlets' summarize the current knowledge of performance of these devices and make clear the over-riding importance of high speed for the future. In all these parts there are large gaps in the detail of what would need to be known in order actually to design a successful aircraft, and further research is required to fill the gaps.

Of course, the present universal restrictions on free discussion by both military classification and industrial proprietary rights have prevented the inclusion of much that is important. In particular, much of the discussion must centre around estimated performance even in areas where test results could have made the problems clearer and more concise.

These same restrictions play havoc with the discussion in Part VI of 'Research in Turbomachinery'. Much valuable material is presented in spite of the fact that each author and discussor knows more than he may say. All the really important research areas are described here and anyone planning research on turbomachinery would do well to read this short and concise review.

The gas dynamics problems chosen for examination were 'Diffusion Flames', 'Detonation Waves' and 'Nozzle Flows with Chemical Reaction'. In each case a summary paper attempted, generally rather successfully, to show the present state of research in each of these areas. In each case the problems are difficult and progress is slow. The author has made clear the nature of recent progress by himself and others. Many photographs and figures, comparing experimental and theoretical results, are included. This book shows essentially that the general nature of gas dynamic-chemical reaction interactions are understood, but that we are in most cases some distance away from accurate quantitative prediction. Even in the relatively simple flow of a reacting mixture through a nozzle there are puzzling discrepancies.

The engine of the future could, in many respects, be produced today if there were materials of construction able to withstand high stress levels at higher temperatures. No engine colloquium would be complete without a discussion of progress on high-temperature materials. It is made clear that active research has, over the past 20 years, developed materials of ever increasing potential for engine construction and that a number of hopeful lines of further inquiry are still open for the future.

Each topic of the book is covered by one or two major review papers, and is followed by extensive discussion extending to many pages and often containing many additional figures with comparative results. Extensive bibliographies are included with each review paper, which would serve well as an introduction to the pertinent literature.

HOWARD W. EMMONS

The Scientific Papers of G. I. Taylor. Vol. III. Aerodynamics and the Mechanics of Projectiles and Explosions. Edited by G. K. BATCHELOR. Cambridge University Press, 1963. 559 pp. £5 or $17.50.

Though it is scarcely possible to give a warmer welcome to this volume than was accorded to its two predecessors one should nevertheless attempt the impossible and do just that. For, of the 58 papers included here about a third are made generally available for the first time. This volume might indeed be subtitled G.I.'s wars, since about half the papers included were written during the two world wars and most of these were directed towards military ends.

The growth of the destructive power of weapons is naturally reflected in the papers. Thus, in his Wilbur Wright Lecture to the Royal Aeronautical Society in 1921 there is an account of the wartime design of steel darts for dropping from aircraft. No one who has heard Sir Melvill Jones's recollections of these early experiments can fail to appreciate the hazards experienced by the observers in the Pyestock chimney experiments nor fail to appreciate the anecdote on page 41. The course of World War II can almost be followed from the papers written in this latter period. That this is so is not surprising, for Taylor's unique ability to seize on the essential physics of an idea and then to quantify it had long been recognized and he was naturally consulted on all major scientific issues. Thus there is the emphasis in the early days of the war on civil defence matters connected with blast waves and their effects on solid bodies, on aircraft problems like icing and the effects of holes in aircraft structures, and on submarine explosions.

Whilst it is true that, with concepts as fundamental as those applied in all Taylor's work, anything stimulated by defensive preparations has its offensive counterpart and vice-versa it is nevertheless possible, with the knowledge conferred by hindsight to back one up, to see in the exceptionally elegant work on fluid metal jets and the Munroe effect in 1942/3 the change from defence to offence. The paper on limiting ranges of large rockets brings however a sharp reminder that all was thenceforward not plain sailing. No one who lived with any inside knowledge through the year between the time when this paper was written and the first arrival of a V2 rocket in London can fail to recall the anxious considerations which faced us. Taylor's paper was the starting-point of a vast research programme which although it dotted the i's and crossed the t's, particularly in relation to the effects of gravity during the finite burning time and of air resistance, obviously did nothing to alter his order-of-magnitude conclusions.

The culmination of Taylor's wartime work must be taken to be the two papers published in 1950 but written several years previously (the first in 1941) on the formation of blast waves from very intense explosions. The second of these contains an analysis of the first atomic explosion in New Mexico in 1945 and shows excellent agreement with, amongst other things, the theoretical prediction made 4 years before the explosion took place that the radius of the blast wave varied as the two-fifths power of the time.

So much for the historical background to many of the papers. What can one say in the space of a review about the diversity of subject-matter in the 58 papers? The main theme, on which it must be admitted there are many variations, is compressible flow. The first paper of all will come as rather a surprise to anyone who thinks that Messrs Rankine and Hugoniot had said all there was to say about the plane shock wave. The history of this subject prior to 1910 makes very interesting reading for it does not appear to be until then that the importance of the second law of thermodynamics in this context was appreciated. Presumably it is to Rayleigh (in a later paper in the same volume of the Royal Society's *Proceedings* as this first paper of Taylor's) that credit must be given for actually saying so in so many words. Taylor, however, all but says it when he speaks, in relation to the kinetic theory of gases, about an irreversible redistribution of velocities and introduces viscosity and conductivity to discuss the nature of the transition in detail, and to show that the transition is in fact a condensation.

Next, chronologically speaking and keeping to the main theme, is a group of papers in which the properties of irrotational flow at near-sonic speeds are investigated and the possible breakdown of this type of flow discussed. It is clear that the ideas in these papers have greatly influenced more recent work on this topic. These are followed by the two classic papers (with J. W. Maccoll) on the supersonic flow past a cone about which it would be supererogatory to comment.

The cone papers may in the broadest sense be regarded as setting the pattern for a number of wartime papers. This is the pattern in which the continuous flow (steady supersonic in the case of the cone, unsteady in the case of blast) is separated from a uniform region of flow (or a region at rest) by a shock wave. Paper 47 concerned with the air-wave surrounding an expanding sphere (written in substance several years before 1946) forms a convenient connecting link, for the method here adopted is exactly analogous to that used in the flow past a cone. For large rates of expansion the flow field is limited as one might expect by the spherical surface and a spherical shock wave. What is not so expected is that at low rates of expansion the sound wave approximation does not afford a good approximation to the pressure in the true motion near the sphere or near the shock wave—for surprisingly enough no matter how small the expansion rate a definite shock wave always exists though naturally of small but nevertheless finite strength.

The atomic bomb papers are, in a sense, very similar. Instead of the inner expanding boundary one now has, as an effective idealization, a finite amount of energy suddenly released in infinitely concentrated form. A similarity solution is possible which, as already indicated, gives excellent agreement with the New Mexico explosion. One surprising feature is that the agreement was obtained using a constant value $\gamma = 1{\cdot}4$ for the ratio of the specific heats of air. As Taylor points out this must imply a neutralization of the expected reduction of γ with temperature by a corresponding increase due to radiation from the centre and absorption in the outer regions. No doubt much further work has since been done. Another interesting feature is the comparison with conventional explosives; here Taylor shows that energy for energy the conventional explosive is the better blast producer due to the effects of the burnt gases left behind by the conventional explosive.

The rate at which the upper surface of the characteristic mushroom rises is obviously, if no more, a matter for scientific curiosity. In the original version of this review I hazarded a guess that Paper 52 on the mechanics of large bubbles rising through extended liquids was sparked off by this question. Dr Batchelor has however been kind enough to apply the brake to my speculations by making reference to unpublished papers which preceded the published version and also by checking with the author himself; he tells me that the reverse was in fact the case. Clearly the mechanics of large bubbles in water was a wartime subject in its own right and it is typical of so much of G.I.'s fundamental thinking that when the need arose to examine the New Mexico observations he had available the necessary theory and experiment for comparison. One need hardly add that the agreement was excellent. Quite apart from these wartime uses of Paper 52 it has proved to be the source of much further thought and research on bubbles in liquids as a subject in its own right.

So much for a very brief look at some of the major contributions in the main theme. One cannnot conclude the review without some mention of the other topics included. Paper 5 written in 1919 in addition to its prime object of discussing the form of parachute for man-dropping includes some interesting observations on parachutes as aeroplane brakes. Paper 10 is a classic showing that even when a wake is present the usual relationship between lift and circulation still holds provided the contour cuts the wake at right angles to the incident stream. Papers 12 and 13 reflect the then current interest in airships whilst Paper 55 on the swirl atomizer is to a mathematician one of the early contributions to three-dimensional bounday layer theory and to an engineer a contribution to the understanding of oil-fired furnaces. One may single out for final mention the Reiner disk paper (written with P. G. Saffman) which arises from an experiment demonstrated by Prof. Reiner at the Brussels International Congress. Here a flat rotating disk is brought close to another parallel disk at rest. The pressure at the centre of the stator disk is recorded and shows, for relatively large clearances, a suction as predicted by Stewartson. However for very small clearances—less than 20 microns—excess pressures of up to half an atmosphere were recorded. Reiner suggested that non-Newtonian properties of the air might be the explanation but Paper 58 which has obvious applications to lubrication theory shows that very small deviations in the assumptions that the disks are truly plane, truly parallel or rotating uniformly without vibration could and probably do account for this phenomenon.

In conclusion, one cannot say more than that this is a volume which every aerodynamic enthusiast—amateur or professional—will wish to possess. To this generation it will commend itself just as, for instance, Rayleigh's volumes did to an earlier generation and still do to this one. This volume does something more than demonstrate G. I.'s universally accepted versatility, for it also shows that even when, as in wartime, he did not feel able to follow exactly the dictates of his imagination in his choice of subject he was just as efficient in pursuing 'directed' research.

L. Howarth

Übungen zur Gasdynamik. By K. Oswatitsch and R. Schwarzenberger. Wien: Springer-Verlag, 1963. 180 pp. DM. 33.20

The German original of Prof. Oswatitsch's compressible-flow text-book *Gasdynamik* appeared in 1952 and the English translation in 1956. One might therefore perhaps have expected that a revised edition would be forthcoming in the near future. The volume under review suggests that this is unlikely. It is a collection of problems covering essentially the same material as the text-book and using the same chapter headings.

Prof. Howarth pointed out in his review of the English translation of *Gasdynamik* (*J. Fluid Mech.* **3**, 1957, 324) that its field was more limited than the chapter headings suggested, the coverage of viscous and turbulent flows and of experimental techniques in particular being far from complete. Today one would in addition emphasize its limitation to ideal gases.

Although non-viscous ideal-gas compressible flow is gradually becoming a smaller part of the whole field of high-speed aerodynamics it nevertheless remains the backbone of any course on the subject, and one must agree with the authors' statement that there is a lack of suitable collections of problems and exercises for use by students and teachers of this subject. As an attempt to fill this gap the book will be a welcome addition to the literature.

It is divided into four parts: 34 pages of problems (255 in all), 100 pages of solutions, 34 pages of equations, and 6 pages of tables. The problems range from the very elementary ones (to find the volume percentages of a mixture of two gases when the mass ratio is known) to the very advanced which almost amount to small research problems (calculation of the supersonic flow past a wing striking a sharp-edged gust). Although, as already mentioned, the material is essentially that of the original *Gasdynamik*, some newer material has been introduced and there are a few references to papers published after 1952.

The relative amounts of space given to problems and solutions show that solutions are given in great detail; in fact they often constitute what might well be described as text-book material.

All the equations in the third section appeared in the original *Gasdynamik* and one might perhaps express surprise that the authors should have found it necessary to repeat them. The reason is given in the preface where it is stated that the book of problems can, except for a few problems, be used independently of *Gasdynamik* or any other text-book in gas dynamics. What the authors mean is presumably that after the student has thoroughly studied the subject he can retire with the book of problems without having to refer to other books. Whether this is the most profitable way of acquiring skill in the use of his knowledge is perhaps open to question.

One difficulty in use by students of a book of this type is touched upon in the preface which says that it must be left to the self-discipline of the user not to look at the solution until all attempts have proved to be in vain or he is convinced that his solution is correct. This might to some students be too severe a test.

To conclude, although in my opinion the scope of the book is somewhat more limited than suggested by the authors, it is a welcome attempt to bring new ideas into the teaching of gas dynamics, and teachers, in particular those at the advanced level, should find in it much interesting material. Is it too optimistic to assume that their mastery of the German language is sufficient to eliminate the need for an English translation?

N. H. Johannesen

Viscous Hypersonic Flow. By W. H. Dorrance. McGraw-Hill, 1962. 334 pp. £4. 17*s*.

This is an ambitious book, aimed at giving its readers a rather thorough understanding of the theoretical approach to, and experimental knowledge of, the wide class of problems within its chosen field. Central among these are the problems of boundary layers in neutral, chemically reacting gases, including laminar and turbulent layers, their interaction with solid surfaces of various kinds (catalytic, non-catalytic, ablating, transpiration-cooled, etc.), results on mass transfer and heat transfer, effects of leading-edge bluntness (including 'strong' interactions of bow shock and boundary layer), and the relevant knowledge of thermodynamic and transport properties of reacting gas mixtures.

The book's ambitious aim seems to the present reviewer to have been most successfully achieved. The author's gift for technical writing and his choice of the right balance between explanation of theory, of data, and of applications, make his book an eminently readable one which can be strongly recommended to students of this important subject.

M. J. Lighthill