REVIEWS

Aerodynamik des Flugzeuges, Band II. By H. Schlichting and E. Truckenbrodt. Berlin: Springer-Verlag, 1960. 485 pp. DM 61.50.

The scale of aeronautical activity in Germany, in both research and development, has been increasing rapidly during the last few years. Such a revival depends on the training of a new generation of aeronautical engineers and research workers, in which the authors of this book must have played an important part. They address themselves particularly to their new generation with the aim of providing a 'sound orientation in this field of knowledge which has expanded so much in the last two decades'.

Volume I, dealing mainly with aerodynamic fundamentals, was favourably reviewed in this Journal last year. Volume II, which concludes the work, comes closer to grips with aircraft. The first half deals with wings of finite span in incompressible flow and with both infinite and finite wings in compressible flow; the second half concerns the aerodynamics of the fuselage, tail and control surfaces.

The authors have collected and systematically organized a great mass of theoretical work, with particular emphasis on practical methods of calculation, and illustrated much of it by examples and comparisons with quantitative experimental data. One's first impression is of an unusually well-digested and clearly presented summary of work much of which was previously to be found only in widely scattered papers. Certainly there is no recent compendium of this kind available in English.

Reflexion on what every young aerodynamicist should know, particularly if a new industry depends on him, leads to some misgivings. This is a stimulating time in aeronautics, not only because aircraft are being designed and built to fly at what yesterday were very high speeds, but also because old ideas of the proper shape of an aircraft, and how it should work aerodynamically, have been upset and need re-examination. This book tends to concentrate too much on flows for which well-established methods of calculation exist.

Its shortcomings may be illustrated by its treatment of highly-swept wings. At low speeds the air flow may separate from the leading edges of such wings as well as from the trailing edges; and when the leading edges are sharp, the separation may begin at quite small angles of incidence. This much is stated and illustrated by a sketch, with reference to original papers, at the end of a 120-page chapter on wing aerodynamics at low speeds. A particular case of the failure at a moderately high lift coefficient of a calculation assuming separation at the trailing edge only, on account of 'separation near the tips', appears halfway through the chapter. The occurrence of leading-edge separation is also mentioned briefly, with further references to original papers, in a very short account of non-linear wing theories and at the end of the chapter on fuselage aerodynamics.

A sound orientation will hardly be imparted without a broader approach. Ideally, the scene should be properly set at the beginning with a review of the aerodynamics of wings from a physical point of view, to encourage the reader to think critically about the assumptions on which methods of calculation are to be based. At the least, the practising aerodynamicist who estimates such things as lift distributions and stability derivatives for swept wings needs to be told a little more about the circumstances in which leading-edge separation is likely to occur, and the ways in which it may invalidate calculations which ignore it.

Other examples of this relative neglect of aspects of aircraft aerodynamics which are not amenable to calculation are mentioned below. Of course, the reader who already has a sound knowledge of the general background is not likely to be seriously misled; but even he might well keep Thwaites' *Incompressible Aerodynamics* handy for its discussions of some of the relevant parts of applied aerodynamics at low speeds, and to fill in other important gaps.

Lifting-line and lifting-surface theories for wings at low speeds are treated very lucidly and at length. (It should be noted that the methods of Weissinger, Multhopp and Truckenbrodt which depend on the $\frac{3}{4}$-chord theorem, or variations on it, are more critically assessed in *Incompressible Aerodynamics*.) There is not much on slender-wing theories, nor, as already mentioned, on the effects of leading-edge separation. The work done in this country during the last ten years or so on wing aerodynamics is only briefly referred to.

The applications of similarity rules to high subsonic and transonic flow about wings are described, and there is a full account of the results of supersonic linear theory. Little or nothing is said to explain the limitations of linear theory in terms of the differences between the flows implied in it and the flows actually observed. Real transonic flow about wings is particularly poorly served. On the other hand there is a useful introduction to hypersonic flow from a more physical point of view.

Singularity-distribution methods for calculating the aerodynamic characteristics of fuselage shapes at small angles of incidence are well presented. Their failure even at moderate angles of incidence is acknowledged, but it is left to the reader to look up the work of Allen and Perkins and others if he wants to know more about that.

The material in the chapter on wings and bodies in combination covers a wide range and includes much that has not been assembled before into a coherent account. Not all of it is very realistic, and again there are some conspicuous gaps. Nevertheless, both this and the final chapters, on the tail surfaces and controls, will be useful to the well-informed and discriminating reader. Here as elsewhere he will need to keep in mind the limitations of inviscid theory assuming well-behaved flow with separation from the trailing edges of the lifting surfaces only.

The text is generously amplified with excellent figures. No high standard of mathematical agility is required of the reader. The deficiencies noted above are offset to some extent by the extensive bibliographies provided at the ends of the chapters, which in themselves will be of special value to many readers for the large number of references which they include to work published in German.

The physical production of the book is superb.

E. P. SUTTON

Boundary Layer and Flow Control. Edited by G. V. LACHMANN. London: Pergamon Press, 1961. Vol. I, 600 pp.; vol. II, 750 pp. £10. 10s. per set of two volumes.

This book is timely in its appearance and is to be welcomed. The very large effort which has been devoted to theory and experiment in the various aspects of boundary-layer control over a long period of years is described mainly in official reports and journals of various countries. Moreover, the pace of theoretical and experimental research is beginning to slacken somewhat, although major engineering applications of many aerodynamically promising forms have yet to be made.

The book is edited by Dr Lachmann, but for reasons he gives in the preface it takes the form of individual contributions by experts from various countries, with no attempt to produce uniformity in style and treatment. As regards the division of chapters into sections and the numbering of these the layout of the book is good, though it would have been better had the chapters also been numbered. The book is amply illustrated with photographs, diagrams and graphs, all of which are well reproduced. One may question the value of some of the photographs of aeroplanes carrying boundary-layer control devices: drawings would have shown these more clearly. Each chapter contains an ample list of references, which enhances the value of the book to the research worker as well as to the designer.

Volume I is divided into two parts. The first part is historical in character with separate accounts of the development of boundary-layer control in Germany, France, the U.K. and the U.S.A. In the second part, the contributions are arranged so that fundamental principles and theoretical methods are followed by experimental methods, with practical applications and special engineering problems concluding.

The following chapters constitute Part I: 'History of boundary-layer control research in Germany', by A. Betz; 'Survey of French research on control of the boundary layer and circulation', by Ph. Poisson Quinton and L. Lepage; 'A brief history of British research on boundary-layer control for high lift', by J. Williams; 'History of research on boundary-layer control for low drag', by M. R. Head; 'The history of boundary-layer control research in the U.S.A.', by J. Flatt. In relation to the other chapters the German contribution is short; and whilst adequate mention is made of the part played by Prandtl in initiating ideas on boundary-layer control, the important contributions by Pretsch and Bussmann to the theory of the stability of laminar boundary layers under distributed suction could deservedly have been given a longer account. The French contribution relates wholly to post-war work and deals with boundary-layer control by suction and blowing, circulation control, blowing at high speeds and the influence of the ground. The two British contributions give an excellent account of boundary-layer control research in this country and cover all aspects of it. From the U.S.A. contribution it is clear that the American effort has been concentrated more on the experimental and practical application aspects than on fundamental theory. Although a fairly complete picture is obtained of the describes the theoretical approach by way of linearized theory. The opinion is expressed that the electric analogy provides the most convenient, flexible method of obtaining numerical solutions, and the chapter which follows this—'The application of the rheoelectric analogy for the jet flap of finite span', by L. Malavard—describes the application of this technique to a finite wing. Comparison of results with experiment show very good agreement.

We come now to the aspects of boundary-layer control which relate to experiment and to practical application and to which seven chapters of Part II are devoted. The first of these—'Experimental methods for testing high lift B.L.C. and circulation control models', by J. Williams and S. F. J. Butler—covers in reasonable detail the various problems and difficulties which beset the experimentalist in this field, and, in particular, tunnel-wall interference may be mentioned. The next three chapters describe the practical application of slots to wings and flaps. One entitled 'Application of the slotted wing to steep gradient and STOL aircraft', by W. Pleines, reviews the historical development of the slotted wing and then discusses its application to STOL-type aircraft. The next, 'Application of l.e. slats to aircraft with swept-back wings', by C. L. Adcock, is a short chapter describing slot effects on swept wing characteristics. A chapter 'The Doublas double-slotted flap', by W. H. Kuhlman, describes a particular development and application of the slotted flap. It is perhaps in these three chapters that one sees the most successful practical application of boundary-layer control so far.

The last three chapters of Part II are devoted to the design and engineering of flap blowing and suction, including the jet flap. These chapter titles are 'Design and engineering features of flap blowing installations', by J. S. Attinello, 'Design and engineering features of flap suction and combined blowing and suction', by F. G. Wagner, and 'Some engineering problems of the jet flap', by I. M. Davidson. The first of these gives a very substantial and detailed contribution on the design problems associated with the practical application of flap blowing to a variety of modern aircraft. The second chapter is also a substantial contribution, in which the emphasis is on the aerodynamic, performance and trim problems which arise when considering the practical application of suction and combined suction and blowing to flaps. The last chapter contains a thought-provoking discussion on thrust and drag aspects of jet-flap aircraft, and it also discusses some of the problems which will be met with in the design of these aircraft, as well as possible engine types and arrangements.

We come now to Volume II, which comprises Part III, 'Boundary layer control for low drag', with eighteen separate contributions, and Part IV, 'Shock induced separation and its prevention by design and boundary layer control', by one contributor.

The first contribution to Part III is entitled 'The nature of transition', by W. Tollmien and D. Grohne, who are authorities in the field of boundary-layer stability. A compact account is given of the theory of small oscillations, followed by sections which discuss the influences of pressure gradient, wall curvature, suction and blowing, density stratification, compressibility and heat describes the theoretical approach by way of linearized theory. The opinion is expressed that the electric analogy provides the most convenient, flexible method of obtaining numerical solutions, and the chapter which follows this—'The application of the rheoelectric analogy for the jet flap of finite span', by L. Malavard—describes the application of this technique to a finite wing. Comparison of results with experiment show very good agreement.

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The next three contributions are concerned with the effects of roughness on laminar flow. They are: 'Effect of two-dimensional and isolated roughness on laminar flow', by I. Tani; 'The effect of distributed surface roughness on laminar flow', by A. E. Doenhoff and A. L. Braslow; and 'Roughness due to insects', by W. S. Coleman. These chapters adequately summarize the effects of roughness, and one may remark that the last shows how patient experimental studies have brought order and understanding into a subject with great inherent difficulties.

There follows a somewhat isolated chapter, 'Progress in the design of low drag aerofoils', by F. X. Wortmann, which points out additional possibilities for improving the design of low-drag aerofoils. After this are four chapters devoted to laminar boundary layers in two and three dimensions. These are: 'Survey of calculation methods of laminar boundary layers with suction in incompressible flow', by W. Wuest; 'Approximate methods of calculating the two-dimensional laminar boundary layer with suction', by M. R. Head; 'Approximate methods of calculating three-dimensional boundary layer on wings', by A. W. Lindfield, H. G. Pinsent and P. A. Pinsent; and 'A stability criterion for three-dimensional laminar boundary layers', by W. B. Brown. The first of these gives a compact survey of exact and approximate methods of computing laminar boundary layers for both continuous and discontinuous suction, and a long list of references is given. The second is concerned with approximate methods of calculation of two-dimensional laminar boundary layers with suction, and in particular a detailed account of Dr Head's own method is given. The third chapter gives an extensive and detailed treatment of the calculation of three-dimensional laminar boundary layers on wings for both incompressible and compressible flow. The last of this group of chapters is concerned with the stability of three-dimensional laminar boundary layers and is quite short. It would, I think, have been better placed if it had followed the first chapter in this volume.

Following these theoretical chapters are five chapters which are devoted to the experimental and design aspects of suction wings. The first of these, 'Research on suction surfaces for laminar flow', by N. Gregory, presents a review of work which has been directed towards achieving a practical suction surface with particular reference to discrete slots and holes and to fine porous surfaces. The second, 'Boundary layer suction experiments with laminar flow at high Reynolds numbers in the inlet length of a tube by various suction methods', by W. Pfenninger, describes fundamental experiments on suction surfaces composed of slots or holes. The third chapter, 'Low-drag boundary layer suction experiments in flight on a wing glove of an F-94A airplane with suction through a large number of slots', by W. Pfenninger and E. Groth, describes a classic series of flight experiments in which full-chord laminar flow was maintained up to a Reynolds number of $3{\cdot}4 \times 10^7$ and a local Mach number of 1·09. The fourth chapter, 'Laminar flow at the junction of two aeroplane components', by J. Goldsmith, is a short account with results from wind-tunnel experiments. The fifth chapter, 'About the development of swept laminar suction wings with full chord laminar flow', by W. Pfenninger and J. W. Bacon Jr., is a very important one in relation to the practical application of boundary-layer control for low drag. Both theoretical and experimental investigations are described, and, in the latter, full chord laminar flow on a 30° swept wing was observed at a Reynolds number of $2{\cdot}4 \times 10^7$ using boundary-layer suction through thin slots.

There follows a chapter, 'Exact solutions of the stability equations for laminar boundary layers in compressible flow', by W. B. Brown. This describes the extension of the Tollmien–Schlichting theory to compressible flow, using accurate numerical methods developed by the author, and applied to a swept wing and flat plate for insulated and cooled surfaces. The next chapter, 'Boundary layer suction experiments at supersonic speeds', by E. E. Groth, discusses experimental results which are important in relation to the performance and economics of projected supersonic airliners.

Then follow two chapters which are devoted to the design aspects of laminar-flow aircraft. The first, 'Fundamental aspects of propulsion for laminar flow aircraft', by J. B. Edwards, is concerned with the performance aspects of the combined propulsion and suction systems considered as an entirety. Though this contains ideas which have been known for many years, it is perhaps the first detailed account of all aspects of this important topic. The second chapter, 'Aspects of design, engineering and operational economy of low drag aircraft', by G. V. Lachmann, is concerned with the various aspects involved in the practical application of boundary-layer control for low drag to economical transport aircraft. As the title suggests, over-all economic savings rather than aerodynamic efficiency is the yardstick by which such aircraft must be judged and by which their design must be guided.

Finally, we have Part IV: 'Shock-induced separation and its prevention by design and boundary layer control', by H. Pearcey. This is almost a book in itself as it occupies 178 pages. There are six chapters or sections to this part: (i) 'Introduction'; (2) 'The nature of shock-induced separation and its presentation for uniform upstream flow'; (3) 'The onset of separation effects for aerofoils and wings', and the 'Influence of geometry'; (4) 'Boundary layer control for aerofoils and wings'; (5) 'Shock-induced separation of laminar boundary layers on aerofoils and wings'; (6) 'Appendix: Notes on the interpretation of the Schlieren photographs'. Chapters 2 and 3 give a concise and readable account of the flow patterns at transonic speeds and of the interaction of boundary-layer effects with compressibility effects. They represent the result of much sifting and analysis of the vast amount of research which has been carried out in this important field. Chapter 4 gives a clear and detailed account of the applications of boundary-layer control to the problem of preventing or reducing the effects of shock-induced separation. Four methods are considered: vortex generators (the account of which is probably the most complete which has appeared so far), air-jet vortex generators, slot blowing, and disturbed suction.

In conclusion one can say that this is a very comprehensive and timely book, which will have a wide appeal, not only to designers and aerodynamicists but also to research workers and students. It covers the many and considerable advances which have been made in every aspect of the study of boundary layers and of boundary-layer control since the basic ideas were first put forward by Prandtl in 1904, and it points the way to increased practical application of the ideas of flow control. It is a pity that flow control in relation to duct flow was not considered separately in this book. The lack of uniformity in style and treatment undoubtedly detracts from the book as a whole, but this is balanced by the expert knowledge and experience available in each chapter. Lastly, for those who have to catch up with their reading whilst travelling, the book would have been more convenient in four volumes, since the heaviest of the present volumes weighs $3\frac{1}{2}$ lb!

J. H. Preston

The Plasma Dispersion Function. By Burton D. Fried and Samuel D. Conte. New York and London: Academic Press, 1961. 419 pp. £4. 6*s*.

In the linearized theory of waves in an infinite, uniform, hot plasma, in which the unperturbed velocity distribution is Maxwellian, the function

$$Z(\zeta) = \pi^{-\frac{1}{2}} \int_{-\infty}^{\infty} \frac{\exp(-x^2)}{x-\zeta} dx \quad (\mathscr{I}(z) > 0)$$

occurs repeatedly, as also does the analytic continuation of this for $\mathscr{I}(z) \leqslant 0$.

The present book comprises a brief introduction, and tables of the complex functions $Z(\zeta)$ and $Z'(\zeta)$ for the range $0 \leqslant x \leqslant 10$, and $-10 \leqslant y \leqslant 10$, where $\zeta = x+iy$. (Values for $-10 \leqslant x \leqslant 0$ follow immediately from symmetry properties.) The tables are thus a good deal more extensive than any previously available, and will be found useful by plasma physicists and workers in related fields.

J. P. Dougherty

Developments in Mechanics, Vol. 1 (Proceedings of the Seventh Midwestern Mechanics Conference, 1961). Edited by J. E. Lay and L. E. Malvern. Amsterdam: North-Holland Publishing Co., 1961. 622 pp. £7. 4*s*.

This volume contains a record of the 31 papers on mechanics of solids and the 18 papers on mechanics of fluids presented at the Seventh Midwestern Mechanics Conference in September 1961. Whereas the papers presented at past Midwestern Conferences have usually been published in two volumes, one on solids and one on fluids, the intention now is to publish them in one volume, and under the auspices of a new continuing organization known as the Midwestern Mechanics Conference. Volumes 2, 3, etc., presumably will contain the papers presented at future conferences.