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REVIEWS

Ventilatoren, 5th edition. By B. ECK. Springer–Verlag, 1972. 576 pp. DM 88 or $ 27.90.

Habent sua fata libelli! It is the fate of all standard works on a given subject to enjoy a limited life of about three or four decades. In respect of quality and importance there is often a culmination in the second or third edition. Eck's book on fans will probably have a similar fate except that it will almost certainly outlive its fifth decade unless in the meantime an entirely new work appears based on more modern concepts and taking into account the latest work in the field of research into turbomachinery. Up till now 'Eck' has been the only standard work in German which has always been quoted either with approval or sometimes critically. It contains a lot of interesting material, and covers the German literature well, especially with regard to the use of fans.

Compared with the fourth edition, which was somewhat overloaded and in parts badly arranged, the new edition is a great improvement, since many of the less important sections have been shortened or omitted. The introduction on fundamentals is not longer limited to centrifugal fans, and the very important problems of noise are completely rewritten by two experts, Regenscheit and Goehlich.

Despite any criticism which may be made about the method of presenting the information, and more particularly the handling of the fundamentals, the book contains an immense amount of worthwhile information over the whole range of very difficult problems connected with design, investigation and use of fans. Every engineer who has to deal with such problems will be wise to consult 'Eck'.

H. MARCINOWSKI

Statistical Fluid Mechanics: The Mechanics of Turbulence, volume 1. By A. S. MONIN and A. M. YAGLOM. English edition, revised by the authors and edited by J. L. Lumley. M.I.T. Press, 1971. 769 pp. £10.50.

This is the first of the two volumes of the encyclopaedic work *Statisticheskaya Gidromechanika* to be translated from the Russian. Volume 1 was originally published in Russian in 1965 by the Nauka Press, in Moscow, and volume 2 was published in Russian in 1967. Volume 2 is not yet available in English, but it will be published by the M.I.T. Press in due course. Any assessment of volume 1 is bound to be influenced to some extent by foreknowledge of the contents of volume 2, since this has an obvious bearing on the overall organization of the work. With this in mind I have scanned through the Russian version of volume 2; the brief description of the contents that follows is derived more from recognition of the equations and the diagrams contained in volume 2 than from an understanding of the text.

Volume 1 starts with a 25-page historical introduction to the topic of turbulence, and then there are five chapters each divided into two major subsections on the following topics: (1) equations of fluid dynamics and their consequences (44 pages); (2) hydrodynamic instability and transition to turbulence (134 pages); (3) method of taking averages; fields of fluid dynamic variables as random fields (17 pages); (4) moments of fluid dynamic fields (35 pages); (5) turbulent shear flows in tubes, boundary layers, etc. (113 pages); (6) the energy balance equation and its consequences (44 pages); (7) generalization of logarithmic layer theory to thermally stratified flows (51 pages); (8) comparison of the theoretical deductions with the data (59 pages); (9) particle dispersion in a turbulent flow; the Langrangian description of turbulence (57 pages); (10) turbulent diffusion (116 pages).

Volume 2, which is somewhat longer than volume 1, is devoted almost exclusively to the problem of homogeneous turbulence. The chapter headings (the numbers run on from volume 1) are: Chapter 6, Mathematical methods for the description of turbulence; spectral functions; Chapter 7, Isotropic turbulence; Chapter 8, Locally isotropic turbulence; Chapter 9, Turbulence and waves; Chapter 10, Functional formulation of the problem of turbulence. Among other things, volume 2 treats in great detail questions of spectral energy transfer, the use of correlation functions in the analysis of turbulence, Kolmogorov's universal equilibrium theory for the small-scale structure of turbulence, and the dynamics of decaying homogeneous turbulence. Some of the recent attempts to construct a rational theory of turbulence (e.g. Kraichnan's direct interaction approximation and Lagrangian history direct interaction approximation) are extensively discussed. The chapter on turbulence and waves is primarily concerned with the scattering of waves (e.g. electromagnetic waves) by turbulence. The final chapter is concerned with the approach to the turbulence problem formulated by Hopf in terms of the characteristic functional.

It will be seen from this excessively brief description that volume 2 is in the main concerned with sophisticated questions, and approaches the turbulence problem at a high-brow mathematical level. By contrast, volume 1 is almost totally concerned with shear-flow turbulence problems of central practical importance. There is a concession to the mathematical reader by the inclusion in volume 1 of two sections ((3) and (4) above) on the mathematical description of turbulence. The concession is slight, however, in that there is in fact a considerable gulf between the sophistication of the methods described in these sections and the use that is actually made of them in the subsequent sessions. For example, although we learn about 'the concept of ergodicity', 'characteristic functions and the characteristic functional', 'determination of the moments and cumulants of a random field according to its characteristic functional', and other such topics in the mathematical sections, the only statistical property that is in fact considered in the subsequent chapters on shear-flow turbulence is the familiar one-point one-time average for the mean velocity field, turbulent energy, and Reynolds stress. I find it a little surprising that the authors have chosen to avoid all reference to measurements of, for example, two-point correlations in shear flows such as jets, wakes and boundary layers. As mentioned above, they do treat correlation functions at length in volume 2 in the context of homogeneous turbulence – but I believe myself that the observed departures of two-point correlation functions from their isotropic form can give valuable insight into questions of turbulent structure in shear-flow problems. It is perhaps a folly to suggest that a book as long as this might be better if it were even longer; but I do believe that in a work of this length and scope the lack of reference to the vast range of experimental measurements of two-point correlations (the paper by H. L. Grant, 'The large eddies of turbulent motion', *J. Fluid Mech.* **4** (1958), p. 149, is typical of the range of papers that I have in mind) is a serious one. For all its length, the book actually contains far less information about the structure of shear-flow turbulence than Townsend's monograph *The Structure of Turbulent Shear Flow*, published in 1956. Admittedly the treatment of Monin and Yaglom is more systematic and certainly more comprehensible than that of Townsend, but in restricting attention to dated approaches to the shear-flow problem (in which eddy viscosity and mixing length are the dominant concepts) they attempt far less than Townsend, and certainly adopt a more conservative approach, reminiscent of the approach adopted by Schlichting in the second half of his well-known text *Boundary-Layer Theory*.

There is also in volume 1 a total lack of reference to measurements of spectra of velocity fluctuations and to the related question of the small-scale structure of turbulent flow. To one reared in the view that Kolmgorov's local equilibrium theory is the one aspect of turbulence theory in which confidence might reasonably be placed, it comes as a surprise to find all discussion of the theory relegated to volume 2, and removed from the context of the shear-flow problem; it is after all the *universality* of Kolmgorov's theory that accounts for its central importance. The degree to which shear-flow turbulence tends (or does not tend!) to isotropy with increasing wavenumber, and the degree to which the $k^{-\frac{5}{3}}$-law and other consequences of the Kolmogorov hypothesis are satisfied, should surely merit discussion in the context of the practical problems considered in volume 1.

Within their self-imposed limits, the treatment of Monin and Yaglom is exceedingly thorough and scholarly. They have clearly been at great pains to develop the subject in a systematic manner, and they have also taken great care to give copious references to original papers. The most valuable chapter for western readers will probably be their chapter 4 (containing sections 7 and 8) on 'Turbulence in a thermally stratified medium', on which topic much of the original work has emanated from the authors' own institute, the Institute of Atmospheric Physics in Moscow. The emphasis here again is on one-point averages, in particular the mean velocity profile, the mean temperature profile and turbulent fluxes of momentum, heat and water vapour. The consequences of similarity hypotheses are worked out in great detail, and with great clarity; this is certainly the most systematic treatment of atmospheric turbulence yet available in book form.

In chapter 5 (containing sections 9 and 10) on 'Particle dispersion in a turbulent flow' at the end of volume 1, attention is first focused on the dispersion of a single particle from a fixed source. Questions of relative diffusion of two or more particles are necessarily postponed till volume 2, because again Kolmogorov's theory is a necessary preliminary. From a modern point of view, this division of the dispersion problem (which admittedly reflects the historical development) leads to a lack of unity in the treatment, which again (in my view) makes volume 1 less attractive as an account of the present state of knowledge and understanding. The Lagrangian description of particle dispersion, dating back to G. I. Taylor's 1921 paper, is of course not dependent on the local equilibrium theory, and Monin and Yaglom follow this Lagrangian approach in their section 9. They translate the effect of the turbulence into an effective turbulent diffusivity (a concept with much sounder theoretical basis than the concept of eddy viscosity), and they derive the various similarity laws for the turbulent diffusivity in jets, wakes and other shear flows. The final section, on turbulent diffusion, is based mainly on the diffusion equation with a turbulent diffusivity. This is preceded by a careful discussion of the interaction of effects due to turbulent convection and molecular diffusivity. The treatment of the diffusion equation with different mean velocity fields, and appropriate distributions of eddy diffusivity, is again almost encyclopaedic in scope.

Given the massive nature of the work, it may be reasonable to question whether the 178-page introductory chapter (sections 1 and 2) is fully justified. It is surely reasonable to assume that anyone tackling such a work must have a reasonable grounding in the 'equations of fluid mechanics' and their elementary laminar consequences. For such readers, section 1 will certainly be superfluous, although it may perhaps be argued that students take particular pleasure in reading what they already understand! Section 2, on instability and transition, is a different matter; this is of course a large subject in its own right, and several textbooks and review articles are widely available (e.g. Lin's *Theory of Hydrodynamic Stability* and Stuart's article 'Nonlinear stability theory' in volume 3 of the *Annual Review of Fluid Mechanics*). Monin and Yaglom's section 2 has the character of a review article, and as such it may well be found useful. It is not, however, a *necessary* preliminary to the chapters that follow, and its inclusion is perhaps to be understood only through consideration of the fact that the book was originally printed in a country where nominal printing costs are substantially less than in the capitalist West! I should perhaps add that inclusion of the Orr–Sommerfeld problem *would* be justified if recent attempts to understand the turbulent boundary layer as a sort of wave-guide (e.g. Landahl, *J. Fluid Mech.* **56** (1972), 775) were also included. Reference is made to the related theory of Malkus (*Proc. Roy. Soc.* A **225** (1954), 196) which invokes ideas of neutral stability of the mean fields; but even the attentive reader would have difficulty in perceiving any link here with the material of section 2.

In spite of these rather negative remarks, I must emphasize that I have the greatest admiration for the immense achievement of the authors in gathering together an enormous amount of material from extremely diverse sources, and putting it all together into an eminently comprehensible and readable account of a branch of fluid mechanics which is probably expanding more rapidly than any other branch (and yet not rapidly enough in relation to its importance). The volume will be invaluable as a reference work, and should find a place on the shelves of all research workers in turbulence theory or experiment. My sole criticism relates to the authors' selection of material, and their, to me eccentric, distribution of the material between volumes 1 and 2. Surely, if the vast effort that has been expended in the past on the theory of homogeneous turbulence is to have any relevance, then an attempt must be made to carry over the ideas of homogeneous turbulence to the context of shear-flow turbulence, and to develop the ideas in this context. Fundamental experiments have been carried out on the distortion of turbulence in distorting ducts of various geometries, and rapid-distortion theory is available to provide a partial explanation of the interaction between mean flow and turbulence in this idealized situation; no discussion of this bridge between homogeneous turbulence and shear-flow turbulence will be found in volume 1, nor, from what I can understand of it, in volume 2. The work is nevertheless to be warmly welcomed, and the English translation of volume 2 will be eagerly awaited. Perhaps the authors may yet produce a volume 3 which will treat the aspects of the shear-flow problem for which they have not found room in the first two volumes.

H. K. MOFFATT

Weather Forecasting as a Problem in Physics. By A. S. MONIN. (Translated by P. Superak.) M.I.T. Press, 1972. 199 pp. $12.50.

The history of numerical weather forecasting is perhaps longer than many dynamicists imagine but it is only in the last decade that the subject has reached a maturity which calls for substantial monographs on the subject. Early in this century V. Bjerknes in Norway was formulating the mathematical equations to describe atmospheric motions, but he did not contemplate numerical solutions. By 1920, L. F. Richardson had studied in detail the problems of solving the equations by finite difference methods and had attempted this with pencil and paper. Neither of these developments received much support from the practitioners of weather forecasting and investigations were not pursued.

It was only when electronic computers and hemispherewide upper air soundings became available in the 1950s that real progress started. A start had been made somewhat earlier in the U.S.S.R. by Kibel, but modern numerical weather prediction can be said to have begun with the work of the Princeton group in the 1950s under the inspiration of von Neumann. Although started in an academic environment the centre of activities soon switched to the meteorological services, and the more recent developments have largely been the work of meteorologists working with a close eye on the practical task of forecasting. Contributions from mathematicians and physicists outside the meteorological field have been few. Thus a review of the subject by an outsider is to be welcomed, particularly if it were to attract the attention and interest of mathematicians with a wider field of experience.

Professor Monin is known mainly for his contributions to the theory of turbulence, but from his book he obviously views numerical weather prediction with the eyes of a mathematician. His interest is to express the prediction problem in terms of formal mathematical equations. This done he leaves it to others to discuss the consequences in meteorological terms, or describe the results of numerical integration. Thus the title of the book under review is somewhat of a misnomer – it should have been "Weather Forecasting as a Problem in Mathematics".

Professor Monin opens his book with a short but useful chapter on the scale of meteorological processes, thereby establishing the relevant dynamical factors. It is interesting to see how a turbulence expert views the interaction of disturbances on various scales in the light of experience of the energy cascade in turbulence.

The second chapter of the book surveys numerical prediction over a period of one or two days. This involves the prediction of features of the pressure field on the scale of depressions and anticyclones. The fundamental problems of numerical prediction are discussed from a theoretical standpoint, but the reader will have some difficulty in visualizing how a numerical forecast is carried out in practice unless he already has some previous knowledge or experience of the matter.

The third chapter deals with the problems that must be faced if there are to be predictions on a longer time scale. Here Professor Monin finds it necessary to provide the reader with more descriptive material on the structure of the atmosphere. Extended prediction for weeks or months must involve an understanding of the air circulation over the whole globe or at least a hemisphere. Professor Monin illustrates some of the peculiar features of this circulation; the circumpolar jet stream and the curious two-year cycle of alternating east and west winds in the equatorial stratosphere. However the description is not really sufficiently complete for the reader to appreciate the remarkable achievement of the numerical simulations of the global circulation which Professor Monin also describes and illustrates. This chapter also contains a discussion of the problem of deciding the extent to which the atmosphere can be regarded as predictable and the way in which numerical simulation has been used to explore this.

The fourth and final chapter contains some afterthoughts on the dynamics of rotating fluids in general, as illustrated by the flow in rotating pans in the laboratory and in the atmospheres of other planets. The roles of various factors, rotation rate, temperature gradient, etc., in determining the type of circulation are discussed here.

This is an intriguing book for a very limited readership. Specialists in dynamical meteorology and numerical weather prediction will be interested to learn how an eminent Soviet turbulence expert views the prediction problem. They will not be disappointed. Professor Monin makes his views clear on a wide range of controversial topics – the relative merit of primitive equation and filtered models, the possibility of effects of solar variations, the significance of the index cycle, clouds as regulators of the general circulation and several others – and there are also unexpected asides on cloud seeding and the carbon dioxide and aerosol problem.

However, the absence of any attempt at a complete development of the basic mathematics renders the book unsuitable as a text for study by anyone who is not already well acquainted with the subject. On the other hand, the presentation is not sufficiently complete to provide a reference book for the specialist. It would be a good but difficult exercise for a post-graduate student to work through the book and attempt to understand it. He would have to refer back to the many original papers quoted but he would have learned a lot.

Although the book is a translation from the Russian, the viewpoint is little different from that adopted by western authors. It may be that Professor Monin did not stress some of the Soviet contributions because they were more familiar to the readership of the original Russian text. The translation is faultless and the symbolism conforms closely with western practice. The book is therefore very easy to read and is well produced.

J. S. Sawyer