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REVIEWS

Hydrodynamics and Heat Transfer in Fluidized Beds. By S. S. ZABRODSKY. M.I.T. Press, 1966. 379 pp. 113*s*. or $15.00.

English-speaking workers on fluidization will welcome this translation of Professor Zabrodsky's monumental work giving an up-to-date survey of the subject till 1963. We have always realized that there is intense activity in the Soviet Union, and this account is of real value in giving a world coverage of the subject. But it brings out two nightmares which must worry any active research worker; namely how to cope with foreign language publications and how to keep up with the literature at all. The book has 1254 references, and it does not deal with all aspects of fluidization; the most important use as a chemical reactor is not mentioned. There are said to be seventy organizations working on the subject in the Soviet Union; and goodness knows how many there are in the U.S.A. This brings to mind the awful thought that in a '1984' of scientific research, big brother will say to the aspiring young worker 'It's all been done before, young man; there is an institute in Novosibirsk which has a library of doctoral theses on your proposed subject of research, not to speak of the establishments in Peking nor yet the several industrial laboratories in Cheshire, Wilmington, Milan and Bombay, who have all had active teams working on your project. No my boy, I suggest you take a management course and go into sales.' My advice to the young man would be to get going and not worry too much about having been preceded. He will certainly not find anything new if he does not start, and his work will probably not be exactly the same as that thesis in Novosibirsk. And even if it is, who cares except the historian of science? The important thing is to discover and find out afterwards whether someone else has done it before. I do not therefore have much sympathy with Professor Zabrodsky when he takes his American opposite number Leva to task for attributing to the Canadians the discovery of the 'spouted bed'. The wretched Leva, we are told, ought to have read *New Methods for the Thermal Treatment of Peat* by Klimov, published in 1939, and other works published in 1948 and 1951; there he would have learned that the spouted bed was invented by Russians and not Canadians. No doubt Zabrodsky is right, though he tells us little about the early Russian work but gives some space to recent Russian work, for example that of Romankov; on the other hand he describes the Canadian work in detail. I for one do not mind who discovered the spouted bed, and if the Canadians had combed the Russian literature, they would have probably done no useful work at all.

This brings me to the second nightmare of what a research worker should do about languages; some scientists are good at languages, but not many. And surveys reveal that scientific information is spread over a large number of languages apart from English. Of course the Russians mostly read English and therefore perhaps it behoves us to read Russian. But what can an active scientist do if he does not read Russian; might he abandon science for a year to learn the language and then find he has added only 10 or 20 % to his coverage of the literature? Surely the answer is to have more translations of research journals and more translations of books like Professor Zabrodsky's. In this respect the Russians are far ahead of us; for many years they have made wholesale translations and we must do likewise.

What is the book about? It gives a solid account of the literature on fluidization, containing for the most part empirical correlations given by laboratory workers using small-scale apparatus. The basic significance of most of these correlations is small, but those who despise such works must acknowledge the difficulty of the problems. The book is written mainly for technologists who have to design industrial fluidized beds and who have to know, for example, how rapidly fine particles are entrained from a bed consisting mainly of coarse particles fluidized at a velocity greater than the free falling velocity of a single fine particle. Such problems are not solved by writing down the Navier–Stokes equations with appropriate boundary conditions; instead, the experimental results are summarized in the form of dimensionless correlations such as that given on p. 152 of the book, viz.

$$\frac{K}{\gamma_g(w_f - w_{ff})} = 1{\cdot}52 \times 10^{-5}\left[\frac{(w_f - w_{ff})^2}{gD}\right]^{0{\cdot}5}\left(\frac{w_f d}{\nu}\right)^{0{\cdot}725}\left(\frac{\gamma_M - \gamma_g}{\gamma_g}\right)^{1{\cdot}15}.$$

The designer tends to cling to such formulae, as a drowning man to a straw, not always recognizing that, because they originate from small-scale experiments, such correlations may be no more relevant to large equipment than a guess. When the formulae turn out to give the wrong answers, we read in the chairman's report of 'teething troubles in large new plants' and wish the Navier–Stokes equations could be solved after all.

The average reader of the *J.F.M.* will not find much to delight him in this book; fluidization has as yet thrown up few simple problems that yield to elegant mathematics, but as I implied when I reviewed an earlier work on fluidization over 10 years ago, there is plenty of food for thought. Since that time some aspects of the subject have been simplified by the application of two-phase flow theories, and this is partly reflected in the present book. But a great deal remains to be done, and I suspect that many of the data in the book are capable of interpretation by the two-phase theory. For example, in chapter 8 there is an account of heat transfer studies in which the heat exchange between fluidizing gas and particles was measured, as for example by Sharlovskaya (page 193). Data such as these might be interpreted in terms of bubble mechanics which are now sufficiently well understood to enable prediction of gas-particle heat transfer coefficients. In this same chapter is an example of dubious dimensionless plotting. Figure 8–11 gives a plot of what appears to be $Nu = hd/k$ (no definition being given) versus $Re = \rho Ud/\mu$; and on page 194 it is stated that '...the Reynolds number varied mainly as a result of changes in the particle sizes'. So in figure 8-11 we are seeing what is roughly a plot of particle diameter versus particle diameter; quite good correlation is obtained.

For the most part the book is very readable and the translators (unfortunately anonymous) and the editor are to be congratulated, although the heading 'Heat transfer with surfaces wetted by fluidized beds' reminds me of those jokes about computer translations.

The book is extraordinarily specialized (and none the worse for that). It does not, as I mentioned above, deal with chemical reactions in fluidized beds—and there seems to be a curious dearth of work on this important subject in Russia, in contrast to intense activity (mostly behind the closed doors of industrial laboratories) in the West. One had hoped that, in a people's republic where patents and profits do not matter, it would have been possible to publish some real data from full-scale plants and thus forward the scientific understanding of large-scale units. But most of the results are from small-scale apparatus (e.g. in the excellent table 10–2 summarizing 29 investigations of heat transfer between fluidized beds and surfaces, the biggest apparatus was 56·5 cm in diameter, small by industrial standards). There is the fascinating centrifugal fluidized bed (p. 301–3) of Gelperin and Ainshtein, in which a rotated bed of particles is fluidized by air flowing radially inwards; this gives the effect of artificially increased gravity, thus suppressing bubble formation. But there is no suggestion of any practical applications, and it may be that the Russians are beset by the same problem as ourselves—that of relating work done in research laboratories with practical needs in industry.

Who will read this book? The research student starting work on a new topic in fluidization will find it an invaluable summary of the literature, even though the book is something of a catalogue giving a short account of each paper without much bringing together of the separate works. The plant designer will find lots of formulae into which he can put numbers. But the formulae will not always agree with one another and he must be careful about definitions of symbols—like this journal, the book does not give a definitive list—and the designer should be careful about extrapolating these formulae, because most of them are for small equipment, and he might be better advised to look at the tables of experimental data, for example those of Martyushin on page 271. Professor Zabrodsky is to be congratulated for including such data rather than merely the dimensionless correlations. A result such as (10-52),

$$Nu_e = 1{\cdot}31 Re_e^{0{\cdot}285}\, Pr^{0{\cdot}33} W^{-0{\cdot}2}\, (1-[r/R])^{0{\cdot}36},$$

has some merits but to summarize data in this way is (effectively) to lose them. For if anyone else wants to re-interpret the data, the task of disentangling the experimental results from the correlation may be impossible. Scientific discoveries were once upon a time concealed within anagrams written in a classical language. The modern equivalent is to present a dimensionless correlation in which most of the 'variables' are not in fact varied. Perhaps the wish for obscure presentation under a veneer of learning is an enduring characteristic of academic scientists.

J. F. Davidson

The Structure of Atmospheric Turbulence. By J. L. LUMLEY and H. A. PANOSKY. Interscience, 1964. 239 pp. 72*s*.

It seems that the first book wholly given over to turbulence was the well-known book by Batchelor on homogeneous turbulence, first published about 15 years ago. Since then, in various countries of the world and in several languages, there have appeared at least ten books on turbulent flow; the theme is becoming something of a fad. Among these the book by Lumley and Panosky is distinguished in that it deals not with turbulence in general but particularly with atmospheric turbulence; although at the same time it does not constitute a monograph on some part of the problem concerning the turbulent atmosphere but attempts as far as possible a full coverage of the theme.

However, from the whole range of material which constitutes atmospheric turbulence, Lumley and Panosky's book leaves two large gaps, both fully understandable to the reviewer. Effectively the authors entirely omit treatment of the widespread, although up till now very badly understood, phenomenon of clear air turbulence which is frequently encountered at considerable altitudes in the atmosphere. Also they have almost totally neglected large-scale atmospheric turbulence, which is very important for the problem of weather forecasting but which on the whole pertains to climatological and meteorological applications of statistical methods rather than those of the mechanics of fluids. Thus, in fact, the book of Lumley and Panosky deals with small-scale turbulence in the lower layers of the atmosphere. However within these bounds the book is complete and systematic, it is written as a text-book and should be useful to students in the field of the mechanics of fluids who are interested in meteorological applications of their discipline, or to students of meteorology who wish to become more familiar with the basis of the theory of turbulence and with practical data on the statistical characteristics of temperature and velocity fluctuations in the lower atmosphere.

The book starts with a chapter on the statistical description of turbulence, that is, the basic information on the theory of random processes and fields which is used in the theory of turbulence. Here is presented (and illustrated with concrete examples) the definition of one-dimensional and multidimensional probability densities and probability distributions, characteristic functions, autocorrelation and cross-correlation functions. Also presented (without strict proof, and unfortunately without adequate reference to literature where one might find such proof) is the basis of the spectral theory of stationary random processes and homogeneous random fields. Since strictly stationary and homogenous random functions do not in fact occur in meteorology, it probably would have made sense to show that spectral theory can be extended to cover a wide variety of processes with stationary increments and fields with homogeneous increments (i.e. locally stationary processes and locally homogeneous fields). Of this, however, in the present book (as with almost all other books on turbulence) nothing whatever is said. An important (and quite useful) innovation of the authors is the inclusion of a special section on the problems of measurement and the interpretation of data on turbulent fluctuations. The specifically geophysical difficulty which arises because of the very wide range of frequencies present in the spectrum of the quantities under study is here overcome with the help of an assumption (based empirically) on the existence of a gap in the spectrum dividing micro-meteorological and synoptic periods.

The next chapter, dealing with the mechanics of turbulence, consists of a discussion of the basic dynamical equations for mean quantities and for the second moments of velocity and temperature fluctuations, which are particularly suitable for meteorological applications (and in particular they concern the important role of buoyancy in the physics of the atmosphere). Here there is a detailed analysis of the process of transfer of energy across the spectrum of homogeneous turbulence and an indication of effects influencing inhomogeneity. On the question of the isotropic small-scale fluctuations, the discussion is based on the results of Kolmogoroff, Oboukhov and Corrsin which lead to a form of the spectral and structural functions of velocity and temperature in the regime of the universal steady state suggested by Kolmogoroff.

The second part of the book deals with experimental data on the profiles of temperature and wind near the earth, on the variances of the three components of velocity and temperature and on the spectra and scales of fluctuations of meteorological fields in the lower atmosphere. To systematize data concerning the lower layers (a few tens of metres thick) extensive use is made of the general theory of Monin and Oboukhov on the similarity of turbulence in the near surface layer of a uniformly stratified fluid. In general the theoretical and experimental results of Soviet authors play a prominent role. The book also presents several semi-empirical or purely empirical interpolation formulae constructed to describe the data. Naturally this second part of the book is already becoming outdated in several places. Thus there exist new data which in some cases contradict and in others reinforce previous data. A more up-to-date and comprehensive survey of the experimental results on turbulence in the surface layer of the atmosphere can be found, for example, in the book by A. S. Monin and the reviewer, *Statistical Hydromechanics*, volumes 1 and 2, the English translation of which is now being prepared by M.I.T. Press. Concerning this, however, it is worth pointing out that our review of empirical data will also, after some time (possibly even by the time the English edition appears) suffer the fate which has already befallen the review prepared by Lumley and Panosky. In general it is quite clear that with the present state of research, a specialist in any given area can only keep up-to-date by means of the current journal literature. However, for students and for specialists in neighbouring fields, who wish to obtain general presentations of areas of study previously unknown to them, of greatest use are moderate sized monographs, written clearly and simply. The book of Lumley and Panosky is a good example of such a work.

A. M. YAGLOM