

The architects have been successful in producing a pleasing exterior by using multicoloured Ravenhead russet brick and Portland stone. The windows, which are double for heat conservation, are in good proportion to the mass of the building. In all, the architects have succeeded in their aim and have provided a dignified building for the undergraduate, and excellent accommodation and facilities for the research work of the staff.

## THE TWO VISCOSITIES OF FLUIDS

A ROYAL SOCIETY discussion on "The First and Second Viscosities of Fluids" was held in the rooms of the Society, Burlington House, on April 29.

The discussion was opened by Prof. L. Rosenhead (Liverpool), who reviewed the fundamental facts and concepts. The generally assumed relationships between the stresses and rates of deformation in a homogeneous fluid lead to equations such as:

$$p_{xx} = -p + \mu' \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) + 2\mu \frac{\partial u}{\partial x}, \quad (1)$$

$$p_{yz} = \mu \left( \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \right), \quad (2)$$

where  $u$ ,  $v$  and  $w$  are the components of velocity referred to fixed orthogonal axes  $Ox$ ,  $Oy$ ,  $Oz$ ;  $p_{xx}$ ,  $p_{yz}$  components of the stress tensor,  $\mu$  the first (or shear) coefficient of viscosity and  $\mu'$  the second (or dilatational) coefficient of viscosity. The combination  $(\mu' + \frac{2}{3}\mu)$ , denoted by  $\kappa$ , is the bulk viscosity.

The physical meaning of  $\mu$  is evident from equation (2), but that of  $\mu'$  depends on the interpretation of  $p$  in equation (1). In the past the bulk viscosity has either been ignored, for which there is some justification if incompressible fluids are being considered, or it has been assumed to be zero, which is true if  $p$  is equal to  $-(p_{xx} + p_{yy} + p_{zz})/3$ . If, however,  $p$  is not equal to this last expression, there is no *a priori* reason for assuming  $\kappa = 0$ , and its actual value (and hence the value of  $\mu'$ ) is open to experimental investigation for any given interpretation of  $p$ . Up to the present, the value of  $\kappa$  has not been measured directly, but values of  $\kappa/\mu$  have been deduced independently from the results of two different types of experiment—the absorption of sound-energy and the determination of the speed of acoustic streaming. In both cases  $p$  is taken as the thermodynamic pressure, defined at constant entropy as a function of  $\rho$ . The former type of experiment is well established, but the latter field was opened up recently by the theory of Eckart<sup>1</sup> and the experiments of Liebermann<sup>2</sup>. Liebermann concluded that there is reasonable agreement between values obtained by the two techniques. It was found that, at megacycle frequencies,  $\kappa/\mu$  is nearly zero for gases and liquefied gases, is 'small' (say 0–5) for bonded liquids, such as water and the alcohols, is larger (5–20) for most organic liquids and largest for a group of non-polar liquids including carbon tetrachloride, benzene and carbon disulphide. The last-named substance has the highest known value with  $\kappa/\mu = 200$  at room temperatures.

These facts, however, merely provide a start, and a number of problems remain. From equations (1) and (2) it can be deduced that the sound absorption coefficient  $\alpha$  is proportional to the square of the

frequency. This is not always found (for example, with carbon disulphide and acetic acid), and deviations are often explained in terms of a 'relaxation' theory. What then is the significance to be attached to  $p$  and  $\mu'$  in equation (1), and how is the theory of acoustic streaming to be modified? Further, there is some doubt about certain aspects of the technique employed by Liebermann for measuring the streaming velocities; this is partly connected with questions of interpretation of results and partly with difficulties intrinsic in the technique.

Experimental questions concerning acoustic streaming were discussed by E. G. Richardson (Newcastle upon Tyne). He recalled that streaming was first recorded with sonic sources by Dvořák<sup>3</sup> and afterwards investigated by Rayleigh<sup>4</sup>, Andrade<sup>5</sup> and Schlichting<sup>6</sup>, who showed that at low frequencies the effect is due to vorticity generated in the boundary layer. Under these conditions recent experiments at Newcastle show that, if the temperature is varied, streaming appears to increase with decreasing viscosity. This also appears to remain true in the megacycle region, even for substances with large bulk viscosity. It was said that dissipative heating of the medium seems to be due to shear viscosity only, and that experiments on absorption of sound in capillaries can be explained in terms of the boundary effects, which are due only to shear viscosity. Richardson suggested that in view of the high vapour pressures of substances with large bulk viscosity, the possibility that cavitation plays a part in the streaming should be kept in mind. In connexion with this point, Prof. P. Biquard (Paris) remarked that, in order to investigate the effect of pressure and the possible effect of cavitation, he has experimented with various liquids at pressures up to about 100 atmospheres by measuring the scattering of light. The results show that absorption of energy under pressure can be accounted for quite simply by taking into account the percentage variation of viscosity with pressure. The question was also raised as to whether the absorption coefficient depends on the amplitude of the source and the hydrostatic pressure. The replies seemed to indicate that the reported measurements made with continuous waves, using pressure-vane techniques, do show a variation with amplitude, but those made with pulsed waves do not. Increase of pressure has been observed to diminish the absorption in carbon tetrachloride and toluene; but this may be ascribed, in part, to changes in the first coefficient of viscosity and the velocity of sound, both of which enter into the Stokes absorption formula.

S. M. Karim (Karachi) mentioned the work he has recently carried out on the Liebermann type of experiment. He pointed out that the values obtained for  $\mu'/\mu$  sometimes appear to depend on the intensity of the sound beam, probably on account of the development of turbulence. Further, the choice of the ratio of the diameter of the sound beam to that of the tube influences the experimental results. Additional detailed experimental work is required before firm conclusions can be drawn.

The difficulties of separating boundary layer effects from Eckart streaming were emphasized by P. E. Doak (Manchester), who went on to show how Eckart's original theory can be extended to deal with relaxing media while still neglecting boundary effects. He reached the conclusion that, apart from a term in the viscosity gradient, the streaming velocity is in all cases proportional to the coefficient

of sound-absorption. Further, it appears that the streaming is generated by interaction between the stationary and the radiative parts of the acoustic field. If either should disappear, or if the motion is one-dimensional, no streaming is possible. Although this work was based on the notion of vorticity sources, the conclusion concerning the role of sound absorption was also demonstrated by J. E. Piercy and J. Lamb (London). They considered the propagation of a sound beam along the axis of a tube. Due to attenuation, there will be a gradient of radiation pressure proportional to the absorption coefficient, and this can be taken as a body force acting on the fluid—which can now be regarded as incompressible. Starting from this point of view, the velocity profile can be found explicitly in mathematical form. Apparatus embodying this principle has been constructed; it aims at a direct measurement of the radiation pressure of the beam, together with a measurement of the pressure-head generated by a known length of beam. Preliminary measurements at 1 Mc./s. and 25° C. show excellent agreement with other techniques for relative values of  $(\alpha/f^2) \times 10^{17}$  ranging from 24 (water) to 5,500 (carbon disulphide).

Both P. E. Doak and R. O. Davies (London) emphasized the fact (due to Mandelstam and Leontovich<sup>7</sup>) that there is no way of distinguishing the effects of a bulk viscosity and a relaxation process associated with frequencies much higher than those of the experiment. The latter author formulated equations of hydrodynamics applicable in a relaxation region and developed the plane-wave solution in order to demonstrate the conclusion just noted. He showed that the presence of relaxation modifies the classical contributions to absorption due to thermal conductivity and shear viscosity. Apart from relaxation associated with intra-molecular vibrational motion (which seems to be present in all liquids with  $\kappa/\mu > 20$ ) there are contributions to the absorption coefficient due to structural changes and shear relaxation which can be investigated experimentally only by working at frequencies comparable with the inverse Maxwell relaxation time.

This aspect of the problem was elaborated by J. Meixner (Aachen), who showed that a liquid can be considered as the limiting case of an elastic body with 'after-effects'. The after-effect theory, when applied to a generalized stress-strain relation containing temperature and entropy, yields an apparent viscosity matrix whose main components become the first and second viscosity coefficients when the substance is isotropic. It is only under certain restrictions that arbitrary after-effect behaviour can be represented as a thermodynamic relaxation theory. When these restrictions are satisfied, parameters referring to shear and volume changes can be separated.

Underlining the fact that stationary transport is to be considered as a limiting case of relaxation, H. O. Kneser (Stuttgart) discussed shear flow and volume flow in gases. In the former case momentum parallel to a wall moving in its own plane is transferred perpendicularly to it with no energy change. The relaxation time is therefore comparable with the collision time and has not yet been observed. When, on the other hand, the wall moves perpendicularly to itself, momentum transfer is coupled with energy transfer and the attainment of a stationary state may be delayed if the molecules have internal mechanisms for storing energy.

J. H. Andreae (Welwyn) and J. Lamb reported further details concerning the intra-molecular relaxation of carbon disulphide centred around 75 Mc./s. at 25° C. and 31 Mc./s. at -63° C. They gave a relaxation theory of absorption involving an arbitrary number of relaxation processes, and then separated effects due to relaxation times much larger and much smaller than the inverse frequency-range of interest. It was suggested that the total magnitude of the volume relaxation still remaining unexplained at 200 Mc./s. can be estimated by assuming that for  $f \rightarrow \infty$ ,  $C_p \rightarrow 5R/2$  and  $C_v \rightarrow 3R/2$ .

Adopting an approach different from that of both the thermodynamic and the molecular theories, Sir Geoffrey Taylor presented a simple mathematical model which exhibits characteristics of a bulk viscosity. He supposes that small gas bubbles are dispersed in an incompressible liquid of shear viscosity  $\mu$ , thus making the medium as a whole slightly compressible. The contraction and expansion of the bubbles are resisted by the viscosity of the surrounding fluid, and it is found that the second coefficient of viscosity is  $4\mu/3v$ , where  $v$  is the (small) proportion of the total volume occupied by the bubbles.

J. G. Oldroyd (Swansea) said that the quantities  $p$  and  $\mu'$  in the basic equations of Prof. Rosenhead's presentation can, in certain special circumstances, be given precise meanings; but this involves the assumption that the values of the quantities are their 'instantaneous' ones.

In summing up the discussion, Prof. E. N. da C. Andrade remarked that the last time he had heard of the second coefficient of viscosity was when he was a student. The late Prof. Karl Pearson had introduced it into his lectures—only to evict it as quickly as possible; it now appeared to be a topic worthy of serious consideration. He pointed out that the second coefficient ( $\mu'$ ) has not been defined in a physical way. But the bulk coefficient ( $\kappa$ )—the quantity used by Sir Geoffrey Taylor in his contribution—is so defined. A method of measuring  $\mu'$  directly is very desirable. The experiments which had been described fell into two classes—those concerned with absorption and those concerned with streaming. From these the ratio  $\mu'/\mu$  has been determined. It is clear, he said, that there are two types of streaming: the type investigated by Schlichting, Andrade and others, and the type which the Liebermann experiment was designed to investigate. There are a number of faults in Liebermann's apparatus, however, which seem to have been eliminated in the excellent experiments of Piercy and Lamb. Richardson had noted that, of the various liquids he used, the five which exhibit marked streaming also possess higher vapour pressures. It appears to be more significant, however, that four of these liquids are non-polar while the fifth possesses only a small dipole moment. As regards absorption of energy in experiments in capillary tubes, Richardson had mentioned that it seems to be chiefly explained by the first coefficient; but this is to be expected, since the skin-friction effect, which involves shearing motion, will predominate in the experiments, so that the second coefficient will not be able to play a large part. The discussion had clarified the two theoretical methods of approach (one based on a formal mathematical presentation and another based on the physical relaxation theory), and it may now be possible to present relaxation theories in terms of formal mathematics. It does not appear strange, he said, that we understand so

little about the second coefficient of viscosity when we realize how little we know about the first. We appear to be at the beginning of a very important study of the internal vibrations of molecules, leading, it is hoped, to a clarification of the fundamental concepts of fluid dynamics. Prof. Andrade stressed the importance of choosing the best fluids for experimental and theoretical work; water is most unsuitable, as it has a wide variety of abnormal characteristics.

A full report of the meeting will appear in the *Proceedings of the Royal Society* in due course.

R. O. DAVIES  
L. ROSENHEAD

<sup>1</sup> Eckart, C., *Phys. Rev.*, **73**, 68 (1948).

<sup>2</sup> Liebermann, L. N., *Phys. Rev.*, **75**, 1415 (1949).

<sup>3</sup> Dvořák, V., *Pogg. Ann.*, **157**, 61 (1876).

<sup>4</sup> Rayleigh, Lord, *Phil. Trans. Roy. Soc.*, **175**, 1 (1884).

<sup>5</sup> Andrade, E. N. da C., *Proc. Roy. Soc., A*, **134**, 445 (1932).

<sup>6</sup> Schlichting, H., *Phys. Z.*, **33**, 327 (1932).

<sup>7</sup> Mandelstam, L. I., and Leontovich, M. A., *J. Exp. Theor. Phys. USSR.*, **7**, 438 (1937).

## OBITUARIES

### Dr. E. M. Elderton

ETHEL MARY ELDERTON was born on December 31, 1878, and died on May 5, 1954. She entered Bedford College for Women in 1895 in the Faculty of Arts and went down in 1899 without having sat for a degree. University was followed by a period of teaching; but the real pattern of her life-work did not emerge until about 1905, when through Alice Lee she worked first for Leonard Darwin and then for Francis Galton, being made secretary of the Eugenics Record Office in 1906. From this modest beginning she became successively Galton Scholar, Galton Fellow, assistant professor and reader in eugenics in University College, London (1931). She retired in 1935.

During the whole of the period in which she was either attached to, or a member of, University College she was actively engaged in both teaching and research. At the College she was a member of a research team headed by Karl Pearson, and as such much of the work she did was contained in the co-operative effort; but evidence that she was capable of a sustained piece of individual research will be found in such a memoir as "Report on the English Birth Rate 1914", to quote only one of a number of publications with a eugenic flavour.

As a person she was delightful, as an expositor she was unrivalled for clarity of thought and lucidity of

expression, and as a teacher she had the rare gift of enthusiasm and the ability to impart it to others. There must be many to-day who owe to her their first steps in statistics and the knowledge and self-confidence that things were not so difficult as more mathematically minded teachers had made them appear. Her essential modesty hid an ability which caused the first Galton Fellow to write in 1906: "Miss Elderton has certainly been a remarkable success at the Eugenics Office; but I think her marvellous energy and quickness to learn anything new would have enabled her to succeed at anything she undertook".

Her work was recognized by the award of the Weldon Medal in 1919, and in December 1931 the University of London conferred on her the degree of D.Sc.

F. N. DAVID

### Dr. W. T. Mathias

WILLIAM T. MATHIAS, lecturer in botany in the University of Liverpool, suffered a heart attack in his laboratory on May 19, and died in hospital an hour or so later. This was a severe blow and shock to his family and friends, for only the previous day he had taken the senior students on a field excursion to North Wales.

He was born in Cardigan, South Wales, in 1900, and graduated in agriculture from the University College, Aberystwyth, in 1922. He then specialized in botany. Although offered a scholarship for research at Oxford, he chose to go to Bangor as an assistant lecturer under Prof. D. Thoday; but a year later, in 1924, he moved to the Botany Department of the University of Liverpool. His early training under Prof. Lloyd Williams led to an interest in the problems associated with the life-cycles of marine algae, and Mathias's published researches on *Callithamnion* and *Phloeospora* were in this field. For some years past he had been making a similar study of *Chordaria*.

Mathias was an enthusiastic and willing teacher, and always carried a large share of the teaching load of the Department. He took an active part in extra-mural work and in school examining, still finding time to help and encourage amateurs in their field collecting. He was for some years secretary of the University Military Education Committee, and took a very keen interest in the welfare and progress of the units associated with the University.

He is survived by a widow and two children; in 1931 he had married Miss Jane Evans, who was one of his former students at Bangor.

ALAN BURGESS

## NEWS and VIEWS

### The Kalinga Prize: Mr. Waldemar Kaempffert

THIS year the Kalinga Prize, which is awarded annually by a panel of judges appointed by Unesco, has gone to Waldemar Kaempffert, who has been science editor of the *New York Times* since 1927 except for the short spell which he spent as director of Chicago's Museum of Science and Industry. Born in New York City in 1877, he is universally regarded as the dean of American science writers. His long and distinguished career has included the editorship of *Scientific American* and *Popular Science Monthly*.

He has written a number of books; but by far the most important part of his life's work has been his writing for the *New York Times*, his regular articles in the *Sunday New York Times Magazine* being particularly popular among laymen and scientists alike. "Current Biography" has justly summed up his career in these words: "No one has done more to bridge the gap between the abstract hypotheses of the laboratory and the mind of the common man". The award will be accepted everywhere as an excellent choice and as a tribute to the great importance of the profession of science writing nowadays. It reflects