

R. R. We

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(1952-53)

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ELASTICITY IN LIQUIDS

A SYMPOSIUM on elasticity in liquids, arranged under the auspices of the British Society of Rheology, was held on March 27 in the Department of Science of the Durham Colleges in the University of Durham. Mr. J. E. Caffyn organized the details of the meeting.

Prof. J. E. P. Wagstaff welcomed the members to Durham, and the morning session then opened with Prof. G. S. Rushbrooke in the chair. Dr. R. Roscoe first read a paper on elastic relaxation and flow in suspensions, in which he referred to the early experiments of Schwedoff on relaxing sols. The method involved placing a gelatine solution in a co-axial cylinder viscometer, suddenly applying a shear by twisting the torsion head which supported the inner cylinder and observing the stress on the system as it relaxed slowly. Schwedoff considered that the stress fell off exponentially; but later workers do not confirm this. Dr. Roscoe has found, however, by repeating their experiments, that departure from the exponential decay is a feature of viscometers with a wide gap between the cylinders. By writing down the flow equations for such an apparatus, he is able to deduce a form of decay for the stress which agrees with experiment.

In the second part of his paper, Dr. Roscoe discussed the relation between rate of shear and shear stress, under steady conditions. Equations of flow have been developed by a generalization of Maxwell's method, which reduce to Bingham's equation in the case of steady flow. The cause of observed departures from Bingham's equation was discussed.

Dr. S. Thornton, speaking on the rheological behaviour of some dispersions of solid particles in liquid media, considered the effect of particle concentration on the relative viscosity of suspensions of rigid non-flocculating particles, and he developed a general expression applicable not only to spherical particles, in agreement with Einstein's well-known equation, but also to non-spherical particles of a limited type over a limited range of concentration. After a brief review of the experimental work on this subject, he stressed the need for checking the absence of flocculation of the particles and for ensuring the validity of any corrections applied. He explained briefly the technique for measuring the absolute viscosity of thixotropic materials which do not exhibit elastic behaviour, and gave results for some special cases.

Dr. E. G. Richardson described some experiments now in progress on the relationship between shear and bulk viscosity. Stokes first deduced a formula for the absorption of plane waves in a gas, the theory making the coefficient (α) proportional to the square of the frequency (f) and the kinematic viscosity (ν). In many liquids α/f^2 is constant (with frequency) but has a value much greater than that of Stokes's formula, if the shear viscosity is substituted for ν . It has been suggested that the bulk, or dilatational viscosity, should be included in ν when the propagation of ultrasonic waves is concerned. One experiment, suggested by Eckart, for the determination of bulk viscosity is based on the mensuration of the acoustic streams in the neighbourhood of a vibrating source, and a study of this is being made using hot wires to measure the streaming velocities in various fluids at frequencies from 1 c./s. to 1 Mc./s. Another method is to study the absorption of ultrasonics in capillary tubes, wherein plane waves are propagated in the centre of the tube and shear waves in the acoustic boundary-layer near the walls. Some initial results in both experiments were quoted.

In the afternoon session, with Dr. J. G. Oldroyd in the chair, J. E. Caffyn and R. M. Underwood described a new method for delineating velocity profiles in visco-elastic liquids. This involves the delineation of the motion of isolated oil drops, suspended in the liquid under test flowing along a tube 1 cm. in diameter, by double-flash photography from two perpendicular directions. From the double exposure of the oil drop on the photograph, the velocity at different radial distances from the axis of the tube can be estimated (and incidentally any deviation from axial flow detected), and hence the velocity profile at the site of the photographs to be constructed. Examples in water (for calibration purposes) and in an ammonium oleate sol were shown. In the visco-elastic fluid the velocity distribution, in accordance with the theories of Oldroyd and of Reiner and Rivlin, is still parabolic.

The final paper, by Dr. A. S. Lodge, considered some theories of the Weissenberg effect, and dealt with the distribution of transverse pressure in a rotating cone-and-plate viscometer, when the interspace is filled with a visco-elastic liquid in which components of stress perpendicular to the direction of shear are set up. The paper was theoretical and dealt with the fluid in stationary laminar incompressible flow, for which the general stress determinant was constructed. The difference between stress components (zero in a Newtonian fluid) give rise to the Weissenberg effect, as Dr. Lodge showed. Having calculated these

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differences for various radial distances in the cone-and-plate apparatus, he can compare the theory with the measurements of Roberts, who erected a series of manometers from the centre to the rim of the cone above the rotating plate and so was able to measure the transverse (vertical) stress distribution in a number of visco-elastic liquids. In the discussion on this paper, Dr. K. Weissenberg pointed out that Roberts's experimental results agree with his own calculation of the stress distribution.

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THE BRITISH SOCIETY OF RHEOLOGY

Bulletin No. 37

April, 1953

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SECOND INTERNATIONAL CONGRESS ON RHEOLOGY

The outstanding event this summer of interest to rheologists will be the International Congress to be held at Oxford between the 26th and 31st July. The provisional programme shows a Presidential Address by Sir Geoffrey Taylor, six invited lectures of general rheological interest and a total of over forty papers on special subjects. Arrangements have been made to hold an exhibition of rheological apparatus by a number of instrument manufacturers, a display of books on rheology and a showing of scientific films. A session will be held to discuss the International Organization of Rheology, a matter that has been featured often in these columns and was the subject of a special resolution at the last Annual General Meeting. In addition to scientific meetings it is intended to hold a Congress Dinner and to arrange a number of excursions for wives accompanying members. There seems every reason to believe that the Congress will prove to be profitable and enjoyable to all who attend.

A.A.M.

GERMAN RHEOLOGICAL SOCIETY

At the same time as the A.G.M. of the B.S.R., held at Southampton last September, a general meeting of the G.R.S. was held in Berlin. The principal questions discussed were those relating to the nature and size of the German delegation to the Oxford Congress, and those relating to methods of improving the Society's financial position, improvements necessary in view of the projected increase in activity.

The Society adopted the view that the most suitable form of the international organization of Rheology was that of an International Union. This decision coincides with the one taken by the B.S.R. at the last A.G.M.

The importance of liaison between the Society and outside research and testing institutes was stressed, and expression was given to the desirability of having representatives from these institutes, who were also members of the G.R.S., on the Committee of the Society.

If recent applications for membership were not included, the membership stood at ninety-three.

Prof. Prandtl was elected honorary member.

P.F.

CORRESPONDENCE.

To the Editor,
British Society of Rheology Bulletin.

Dear Sir,

I do not think that my good friend, Dr. Swainger, is quite fair in describing the self-imposed limitations of the scope of the Second International Congress as "inconsistent." The position is as follows.

Bingham's definition of "Rheology" as "The Science of the Deformation and Flow of Matter" is universally accepted; but certain types of problem concerned with deformation and flow are already dealt with by International Unions such as that of Theoretical and Applied Mechanics which hold Congresses of their own. At the time of the First International Congress on Rheology, the sponsoring "Joint Commission on Rheology" agreed that, while accepting Bingham's definition, neither the Commission nor the Congress should deal with those subjects which, while falling within the Bingham definition, were actually being dealt with by other international bodies.

There is one further consideration: at our last A.G.M. (as reported on p. 3 of Bulletin No. 36) we resolved that, in principle, we consider the appropriate form of International Organization of Rheology to be an International Association affiliated to the International Union of Pure and Applied Physics. The President of I.U.P.A.P. has made it quite clear to me that his Union would not favour such an arrangement if the proposed Association included in its terms of reference fields of study already adequately catered for by other international bodies, a proviso which seems to be very reasonable.

But the British Society of Rheology, as far as internal policy is concerned, is quite at liberty to discuss hydrodynamics, aero-dynamics, or pure theory of elasticity if and when this seems desirable. Many problems concerning viscosity of gases, in which the nature of the gas is of importance; and much of the rheology of solid bodies, again with the emphasis on the differentiation of materials, would come, in any case, within the scope of the Congress as it is quoted by Dr. Swainger.

G. W. SCOTT BLAIR,

Hon. Org. Secretary,

2nd Int. Cong. on Rheology.

6th February, 1953.

SUMMARIES OF PAPERS
read at meetings of the Society

The Rheology of Butter and some other fats

J. H. PRENTICE

(Nat. Inst. for Res. in Dairying, Reading.)

Butter is a somewhat imperfect emulsion of water in butterfat, the butterfat itself consisting of a mixture of crystalline, plastic and liquid fats, together with some globules of solid fat in suspension. In addition some air is usually occluded within the emulsion.

From the rheological point of view a good butter should be easy to mould into shape in the packing machine, firm enough to retain its shape during subsequent handling, and then easily spreadable upon bread. So far the approach to the study of the rheological properties of butter has been purely empirical.

Spreadability may be assessed by subjective methods, which give fairly reliable results with a panel of trained observers, but the accuracy is not sufficient to distinguish small differences between samples. In seeking an instrumental test to replace the subjective one, the only guidance obtained from a study of the action of spreading is that the deformation of butter at fairly high speeds is involved. An extrusion type of apparatus, such as was originally described by Griffiths in 1931, but modified to extrude the butter at a constant rate, has proved to give estimates of spreadability at least as reliable as those given subjectively by a panel of experts.

The firmness of butter has been studied by means of compression under a steady load. When a suitable load is applied to a sample there is an initial instantaneous deformation, followed by a plastic flow, which may continue indefinitely; when the load is removed, there is a sudden recoil, followed by a slow, partial recovery.

These instrumental methods, among others, have been used to study variations in the rheological properties of butter. The influence of temperature is very great. Almost all butters are quite firm and easily handled below 50°F., few can be easily handled at 65°F., and hardly any at 70°F. Storage, too, has its effect. The process of "firming up" which takes place immediately after manufacture is really only the early stage of a process which continues at least as long as the butter remains wholesome.

The behaviour of margarine and compound fat is very similar to that of butter.

Paper read 11th December, 1952.

A Constant Stress Rheometer for the Investigation of Visco-elastic Materials

E. N. THROWER and A. R. LEE
(D.S.I.R., Road Research Laboratory).

A servo-controlled constant stress rheometer for the investigation of the visco-elastic properties of materials of high consistency (from 10^7 – 10^{12} poises) is shown. It employs the compression of cylindrical specimens between 1–2 in. long, under a constant stress, the necessary load variations being made automatically by a simple analogue computer. The load is applied to the specimen by a weight travelling along a balanced beam supported on knife-edges, and can be removed for the measurement of elastic recovery. Both recovery-time and deformation-time curves are recorded on a chart carried by a revolving drum; the servo system employed reduces almost to zero the load imposed on the specimen by the recording gear.

For a purely viscous, inelastic liquid, the value of the coefficient of viscous traction, λ , as defined by Trouton, is obtained, and the question arises of the relation between this and the coefficient of viscosity, η , in simple shear. For a Newtonian liquid, Trouton's relation, $\lambda=3\eta$, is clearly valid. For a non-Newtonian liquid, however, whose coefficients of viscosity and viscous traction are functions of the stress or flow such a relation could hold only if the parameters upon which the two values depend are equal in the two tests. In viscometers of the concentric cylinder type, the viscosity can be measured as a function of the velocity gradient or shearing traction in simple shear, but in simple compression this relation is meaningless. The viscosity of an isotropic liquid, however, is a scalar, and as such can be a function only of other scalars, i.e. of the three scalar invariants of the stress or flow tensors. Trouton's relation will therefore be valid in general only if the three invariants of the flow tensors are equal in the two kinds of deformation, a condition which it is impossible to fulfil. The first invariant of the flow tensor is equal to the volume flow, which for almost all materials is zero; we can therefore confine our attention to the second and third invariants. The viscosity in simple shear, for which the third invariant is zero, is a function only of the second invariant; physically, this implies that the viscosity is a function of the power absorbed per unit volume. In simple tension or compression, however, the coefficient of viscous traction is a function of both second and third invariants; if experiments are made using the three tests at the same value of the second invariant, the effect of the third can be investigated.

The theoretical analysis of the limitations on Trouton's relation for non-Newtonian liquids is summarised from an unpublished paper by A. R. Lee, M. Reiner, R. Schoenfeld-Reiner, and E. N. Thrower, "Non-Newtonian flow in shear, compression and extension."

Paper read 9th January, 1953.

RHEOLOGY ABSTRACTS

2563. *Oversea-Post. Engineering Edition. English Edition.* No. 1. Vol. 1. Page 170.

A description of a new version of the Viscograph manufactured by the Brabender Company of Duisburg. D.C.B.

2564. **Measurement and importance of elastic properties of metals.**

Nature (London) **170**, 527-9 (Sept. 27, 1952).

Report of a conference at the National Physical Laboratory during March 20-21 (1952).

2565. **Measurements with a Höppler Viscometer.**

B. ALBRECHT. *Arbeiten des Paul Ehrlich Inst.*, Frankfurt a/M. 1950, No. **48**, 30.

A Höppler viscometer was used for obtaining measurements on horse, sheep and immune horse serum and on physiolog. NaCl soln., in the presence and absence of small percentage phenol. The viscosity of sheep serum differs from that of humans and horses.

2566. **Mechanical properties of cellulose fibres in relation to internal structure.**

F. ANDERSEN. *Trans. Danish Acad. Techn. Sci.* 1950, No. **3**.

The static (E_s) and dynamic (E_d) moduli of elasticity of cotton and rayon fibres were determined. The fibre is mechanically conditioned by the first application of stress and then gives reversible stress-strain relationships. Cotton gives a linear stress-strain curve, whilst rayon gives a curvilinear relationship. The effect of humidity and relaxation were studied in detail.

2567. **A surface effect in the creep behaviour of polycrystalline lead.**

E. N. DA C. ANDRADE AND A. J. KENNEDY. *Proc. Phys. Soc. B.* 1951, **64**, 303.

2568. **A high shear method of rating brushability of paints.**

W. K. ASBECK, D. D. LAIDERMAN AND M. VAN LOO. *J. Coll. Sci.* 1952, **7** (3) 306.

2569. **Difference in viscosity of ortho- and para-hydrogen at low temperatures.**

E. W. BECKER AND O. STEHL. *Phys. Rev.* 1952, **87**, 525.

2570. **The flow of polystyrene through rectangular channels.**

C. E. BEYER AND F. E. TOWSLEY. *J. Coll. Sci.*, 1952, **7**, (3), 236.

2571. **A theoretical examination of the plastic deformation of crystals by glide.**

J. F. W. BISHOP. *Phil. Mag.*, 1953, **44**, 51.

2572. **The viscosity of gaseous ^3He at low temperatures.**

J. DE BOER AND F. G. D. COHEN. *Physica*, 1951, **17**, No. 11-12, 993.

At temps. below 5°K the viscosity of ^3He calculated by quantum mechanical expressions is about twice that calculated from the viscosity of ^4He taking into account the difference in mass. The nuclear spin has a marked influence. E.W.J.M.

2573. **The rheology of plastic dispersions.**

P. A. BRISCOE, W. J. DUNNING AND R. C. SEYMOUR. *Brit. J. Appl. Physics*, **3**, 193, 1952.

An account is given of the behaviour of a system containing 80% by vol. of a powdered solid, which shows plastic deformation but does not conform to the Bingham or

Freundlich concepts of plasticity. The term "dilatant plasticity" is suggested for such systems which have a small sedimentation vol., are dilatant, non-thixotropic, and can be moulded, but shear-harden, showing a series of yield values dependent on their previous history. Under a force exceeding one yield value, deformation does not proceed continuously but approaches a limiting value. The deformation properties of this system are characterized by two parameters: k measures the shear-hardening due to changes in the geometry and structure of the powdered solid, and c expresses the relation between the limiting compression and the weight required to produce it with roll milling; the parameters change in a reciprocal way, the product kc remaining approx. constant.

B.C.R.A.

2574. Viscosity, self-diffusion, and allied effects in solid polymers.

F. BUECHE, *J. Chem. Phys.*, 1952, **20**, 1959.

An attempt has been made to explain the observed viscous behaviour of bulk polymers. It is found that the viscosity and diffusion may be represented by a theory which takes into account the coupling together of the molecules. Two equivalent treatments are given. One makes use of a segmental friction factor in the same manner as the common formulation of dilute solution viscosity of polymers. The second method uses the concept of segmental jumping. Since both are equivalent, an expression for the friction factor is found in terms of the segmental jumping frequency. Using this fact it is possible to calculate the segmental jumping frequency from bulk viscosity data. A simple application leads to the result that the jumping frequency is about 0.3 sec^{-1} at the transition temperature in polystyrene.

In addition a simple relation is found to hold between bulk viscosity and diffusion constant. The proportionality constant is easily evaluated and so one is now able to obtain self-diffusion constants directly from viscosity data.

AUTHOR.

2575. The nature of the coefficient of friction.

J. T. BURWELL AND E. RABINOWICZ. *J. Appl. Phys.*, 1953, **24**, No. 2, 136.

2576. Viscosity of glass.

W. CAPPS. *J. Colloid Sci.*, 1952, **7**, 334.

A review of some methods for measuring viscosity and of some of the work of various authors in relating their data to the structure of glass and to the size of the units participating in the flow process. The range of measurements covers from about 10^2 poises to about 10^{15} poises at temps. up to $1,400^\circ\text{C}$. An outline is presented of some attempts that have been made to extend the kinetic theory of gases and solid-state theories to the liquid state. The relative importance of ionic size and inter-ionic binding forces in various temp. ranges is discussed for some binary alkali silicates. Evidence is given that many glasses are Newtonian liquids in both high- and low-viscosity ranges.

B.C.R.A.

2577. The stability of viscous flow between rotating cylinders in the presence of a magnetic field.

S. CHANDRASEKHAR. *Proc. Roy. Soc. A*, 1953, **216**, 293.

2578. The fractures produced in glass and plastics by the passage of stress waves.

D. G. CHRISTIE AND H. KOLSKY. *J. Soc. Glass Technol. (Trans.)*, 1952, **36**, 65.

2579. An investigation of cracks and stress waves in glass and plastics by high-speed photography.

D. G. CHRISTIE. *J. Soc. Glass Technol. (Trans.)*, 1952, **36**, 74.

2580. Implications of Philippoff flow curves for the determination of intrinsic viscosity of high polymer nitrocelluloses.

C. M. CONRAD AND H. M. ZIFFLE. *J. Coll. Sci.* 1952, **7** (3), 227.

2581. The Rheology of blood—A survey.

A. L. COPLEY. *J. Coll. Sci.*, 1952, **7** (3), 323.

2582. Constant stress elongation of soft polymers: time and temperature studies.

C. A. DAHLQUIST AND M. R. HATFIELD. *J. Coll. Sci.*, 1952, **7** (3), 253.

2583. Investigations in the field of rubber vulcanization. X: Vulcanization of natural rubber with mixtures of sulphur dioxide and hydrogen sulphide. (In Russian).

B. DOGADKIN AND F. KHEIFETS. *Koll. Zhur.*, 1952, **14**, 157.

(See No. 2628).

2584. Physical properties of liquid fluorine.

G. W. ELVERUM AND R. N. DOESCHER. *J. Chem. Phys.*, 1952, **20**, 1834.

From measurements on the temperature dependence of viscosity it is concluded that fluorine acts as a normal liquid in the region studied (70° to 83°K). S.T.

2585. Thin liquid jets.

J. L. ERICKSEN. *J. Rational Mechs. and Anal.*, 1952, **1**, No. 4, 521.

The paper describes a stability investigation for jets not axially symmetric, based on Boussinesq equations of motion for thin liquid jets, taking into account surface tension and body forces. E.W.J.M.

2586. On the thermodynamic theory of the elastic after-effect.

N. S. FASTOV. *Zh. Eksper. Teor. Fiz.*, **22**, 487–92 (No. 4, 1952), *In Russian*.

Integro-differential equations of motion are derived and solved, showing that at any given moment the stresses in a uniform isotropic body depend on the deformation and temperature at that instant, and on the entire deformation history, but not on the temperature history; whilst the strains depend on the instantaneous stresses and temperature and on the history of both. The theory is applied to the study of the propagation of a longitudinal elastic wave in an infinite medium, taking into account relaxation phenomena. SCI. ABSTR.

2587. Temperature variation of the elastic moduli of glass.

J. V. FITZGERALD, K. M. LAING AND G. S. BACHMAN. *J. Soc. Glass Technol. (Trans.)*, **36**, 90, 1952.

Temp. regions of non-elastic behaviour are typical of glass, and can be utilised to gain a better understanding of its structure and mechanical behaviour. Stress-induced thermal diffusion, stress-induced ionic diffusion, and certain other phenomena that require time for their completion, are processes which cause irregular elastic behaviour. These processes manifest themselves in various ways, such as internal friction peaks, relaxation of elastic moduli, and recoverable creep. For example, the variation with temp. of dynamic shear modulus of plate glass, a typical soda-lime-silica glass, can be explained by referring to the more easily understood variation with temp. of the internal friction. B.C.R.A.

2588. The dependence of the intrinsic viscosity of sodium polyacrylate on salt concentration.

P. J. FLORY, W. R. KRIGBAUM AND W. B. SAULTZ. *J. Chem. Phys.*, 1953, **21**, 164.

The intrinsic viscosities of sodium polyacrylate solutions have been determined. It is concluded that the results bear out, at least approximately, the theory previously developed for the intrinsic viscosities of non-ionic polymers. S.T.

2589. Dilute solution hydrodynamic behaviour of flexible chain molecules : polymethyl methacrylate.

T. G. FOX AND L. MANDELKERN. *J. Chem. Phys.*, 1953, **21**, 187.

Sedimentation, diffusion, viscosity and light scattering data on polymethyl methacrylate solutions are correlated successfully, furnishing evidence for the validity of the theory proposed. S.T.

2590. Investigations on the rheological properties of confectioners' doughs. (In Russian).

T. YA. GORAZDOVSKIĬ. *Koll. Zhur.* 1952, **14**, 408.

Using a method described elsewhere (Zav. Lab. 1949, **5**, 554, Torfnaya Prom., 1949, No. 8), the author has studied quantitatively the effect of the presence and absence of sugar on elastic and plastic deformation and on shortness of bread and biscuit doughs. Load deformation curves in general confirm earlier work. G.W.S.B.

2591. Experiments on the mechanics of rubber—II. The torsion, inflation and extension of a tube.

J. R. GOULD. *Proc. Phys. Soc. London B.*, 1952, **65**, 905.

Letter on No. 2512.

2592. The observation of polyhedral sub-structures in crystals of silver bromide.

J. M. HEDGES AND J. W. MITCHELL. *Phil. Mag.*, 1953, **44**, 223.

Micrographic evidence of dislocations, which were made visible by the photolytic precipitation of silver along them, is given. P.F.

2593. The effect of hydrogen on the tensile properties of steel.

J. D. HOBSON AND J. HEWITT. *J.I.S.I.*, 1953, **173**, 131.

2594. Fine structure and rheological properties of lithuim soap-oil dispersions.

B. W. HOTTEN AND D. H. BIRDSALL. *J. Coll. Sci.*, 1952, **7** (3), 284.

2595. The laws of friction.

H. G. HOWELL. *Nature*, 1953, **171**, 220.

Author claims that the force of friction between textile fibres obeys a relationship $F=a.R^n$ (F =force of friction, R =normal load), where the parameter n may have values between 0.67 for nylon and 0.96 for cellulose acetate. If experimental justification is forthcoming for the above relationship, the implication is that a is not dimensionless in the case of textile fibres. R.S.

2596. Relaxation of tension in stretched dough.

I. HLYNKA AND J. A. ANDERSON. *Canad. J. Tech.*, **30**, 198–210 (July–Aug., 1952).

In essence, a motor-driven carriage stretches a ball of dough, impaled on a split-pin holder, to a preset distance, and holds the sample at constant length during the relaxation process. One of the dough stretching pins is connected through a steel spring to a strain gauge; a small displacement of the pin moves an iron slug in the field of a differential transformer, the voltage output of which is coupled to a kymograph by a suitable electronic system. The relaxation of dough under external tension is characterized by a linear relationship between tension and the logarithm of time and may be described by a single parameter, namely the slope of this function. Mathematically, the slope is the product of two variables, the rate of change in tension, and time, i.e. $-K=t(dS/dt)$. Relaxation of the type studied in this investigation has been reported in the literature to only a limited extent and a satisfactory theoretical basis still remains to be developed.

SCI. ABSTR.

2597. The band viscometer.

H. H. HULL. *J. Colloid Sci.*, **7**, 316, 1952.

The band viscometer, first described by Wachholtz and Asbeck, is not well known and has not been applied by others to rheological work at high rates of shear. This is

unfortunate, for the band viscometer has four important advantages : (1) The sample is subjected to a uniform shearing force throughout; (2) the heat energy formed in the sample during testing is dissipated efficiently; (3) it operates effectively at rates of shear up to 10,000 reciprocal sec., which is higher than the more commonly used rotational-cup viscometers; (4) the test is quick and the instrument is easy to clean. B.C.R.A.

2598. On the oscillating cylinder viscometer, I.

A. A. K. IBRAHIM AND A. M. KABIEL. *J. Appl. Phys.*, 1952, **23**, 1190.

Results are presented to show that the theory of the oscillating cylinder viscometer (Abstract 2525) is satisfactory for predicting the viscosity of a Newtonian fluid. S.T.

2599. Rheology of metals at elevated temperatures.

A. E. JOHNSON AND N. E. FROST. *Journ. Mech. & Phys. Solids*, 1952, **1** (1), 37.

Investigation of general stress, time and temp. dependence of creep, plastic strain and relaxation properties of steel, Al alloy, Mg alloy and a few other alloys. Examined materials were typical engineering metals, different in their basic structure to allow presumably divergent behaviour. Experiments included : combined stress-creep tests under constant load; same tests under variable load systems; fracture after creep under combined stress; relaxation and its relation to creep; time-independent plastic strain at elevated temp under constant load; fracture at elevated temp. in short-time plastic-strain tests. Nature of inferences from results obtained discussed.

BIBLIOGR. INDUSTR. DIAMOND APPL.

2600. The rheology of a lubricating oil at temperatures below the pour point.

S. P. JONES AND J. K. TYSON. *J. Coll. Sci.*, 1952, **7** (3), 272.

2601. Rheological properties of a high asphaltene content bitumen.

N. KLEIN. Letter in *Bull. Res. Coun. Israel*, **2**, 66-7 (June, 1952).

The total elastic recovery was measured in a conical cylindrical viscometer for different displacement and loads. The recovery strain/displacement curve shows peaks at small displacements. An interpretation in terms of entangled coils of hydrocarbon chains is suggested. SCI. ABSTR.

2602. The mechanical and thermal properties of gas compression cables.

N. KLEIN. *Appl. Sci. Res.*, 1952, **A3**, 361.

The mechanical and rheological properties of gas compression cables subjected to inside and outside pressure are investigated with a specially made gauge and the thermal expansion coefficient is measured. P.G.M.

2603. On the elastico-viscous properties of phenolformaldehyde resins (In Russian).

B. M. KOVARSKAYA AND S. I. KLAS. *Koll. Zhur.*, 1952, **14**, 425.

Various experiments especially of temperature coefficients of viscosity and elastic modulus. G.W.S.B.

2604. Direct determination of the flow curves of non-Newtonian fluids.

I. M. KRIEGER AND S. H. MARON. *J. Appl. Phys.*, 1952, **23**, 1412.

Errors which appeared in the original paper (Abstract 2466) are corrected. S.T.

2605. On the work of G. M. Bartenev on the Thermodynamic theory of elasticity of synthetic rubbers (In Russian).

E. V. KUVSHINSKIY. *Koll. Zhur.*, 1952, **14**, 227.

(Criticism and reply by G.M.B.)

G.W.S.B.

2606. On the squirming motion of nearly spherical deformable bodies through liquids at very small Reynolds numbers.

M. J. LIGHTHILL. *Commun. pure appl. Math.*, **5**, 109-18 (May, 1952).

2607. Modified method for viscosity measurement of small samples.

J. G. LILLARD. *Anal. Chem.*, **24**, 1042, 1952.

The viscometer was designed for use with sample vols. of less than 0.1 ml. In principle, the apparatus is based upon the rate of flow of a drop of liquid between two fixed points in an inclined capillary tube. To obtain a suitable efflux time, the angle of inclination of the tube may be varied in accordance with the viscosity of the sample.

B.C.R.A.

2608. A method for measuring the flow point of glass.

H. R. LILLIE. *J. Amer. Ceram. Soc.*, **35**, 149, 1952.

The need for a new reference point for glasses, at a temp. substantially above the softening point, is discussed in connection with the development of new glasses, control of properties, and behaviour in applications where reworking is required. An apparatus and a procedure are described by which a fibre elongation test indicates the "flow point," or temp. at which a glass reaches a viscosity of 10^5 poises. A short section of a glass fibre, nominally 0.65 mm. dia., is heated under specified conditions of load and heat application. The heating time required for the fibre to draw down to a thread indicates the temp. attained. When properly standardized with one or more known glasses, the precision is equivalent to from 1°C. for soft glasses to 5°C. for hard glasses. The effect of infra-red absorption by the sample is examined, and a correction curve is given for use when such absorption is abnormally great.

B.C.R.A.

2609. The viscosity of binary liquid mixtures.

F. W. LIMA. *J. Phys. Chem.*, 1952, **56** (9), 1052-54.

A formula is proposed for the viscosity of binary liquid mixtures as a function of the viscosity and density of the pure components and the density of the mixture. It is applied to various mixtures of organic liquids and shown to give good agreement.

G.E.B.

2610. Temperature dependence of viscosity of associated liquids: erratum.

T. A. LITOVICH. *J. Chem. Phys.*, 1952, **20**, 1980.

The suggested temperature dependence of the activation energy of associated liquids (Abstract 2534) does not hold over a large range of temperature for methyl, ethyl, or propyl alcohols.

S.T.

2611. Internal deformation as a characteristic of clay.

P. MAACK. *Ziegelindustrie*, **5**, 115, 1952.

The author writes at length of the inadequacy of the existing methods for the determination of plasticity and describes a new method based on the measurement of the deformation work within a mix subjected to torsion. The method involves a "torsion-plastograph" and auxiliary apparatus for the ageing of clay and for a rapid determination of the percentage of mixing water.

B.C.R.A.

2612. A property of Bessel functions and its application to the theory of two rheometers.

H. MARKOVITZ. *J. Appl. Phys.*, 1952, **23**, 1070.

A method of expanding expressions of the type $J(\xi)Y(\sigma) - J(\sigma)Y(\xi)$ and $J'(\xi)Y(\sigma) - J(\sigma)Y'(\xi)$ is given. Here J and Y are Bessel functions of the first and second kind. These forms occur frequently in physical problems with cylindrical symmetry. The type of expansion used here can be used with other functions that are solutions of second-order differential equations. The use of these expansions allows the development of theories for two rheometers used for determining dynamic mechanical properties of liquids. In these mathematical treatments, the inertia of the sample is taken into account.

AUTHOR.

2613. Residual stresses and strains in moulded plastics.

W. H. MARKWOOD AND H. M. SPURLIN. *J. Coll. Sci.*, 1952, **7** (3), 244.

2614. Viscosities of several liquids.

D. M. MASON, O. W. WILCOX AND B. H. SAGE. *J. Phys. Chem.*, 1952, **56** (8), 1008-1010.

The viscosity of ethylenediamine at 30° to 210°C., ethylenediamine hydrate at 30° to 170°, hydrazine at 10° to 80°C., and isopropylamine at 0° to 180°C. in the liquid phase are measured using a steel rolling ball viscometer at pressures from bubble point to 250 atm.; also of fuming nitric acids at 10° to 120° and furfuryl alcohol at 30° to 130°C. in a glass rolling ball viscometer at bubble point. G.E.B.

2615. Crystal fragmentation in aluminium during creep.

D. McLEAN. *J. Inst. Met.*, 1953, **1**, 287.

2616. Grain-boundary slip during creep of aluminium.

D. McLEAN. *J. Inst. Met.*, 1953, **1**, 293.

2617. The long range elasticity of hair keratin.

K. H. MEYER, A. J. A. VAN DER WYK, W. GONON AND C. HASSELBACH. *Trans. Faraday Soc.*, 1952, **48**, 669.

2618. The viscosity of gaseous uraniumhexafluoride.

A. L. MEYERSON AND J. H. EICHER. *J. Am. Chem. Soc.*, 1952, **74**, 2758.

2619. A generalized fluidity power law and laws of extrusion.

M. MOONEY AND S. A. BLACK. *J. Colloid Sci.*, **7**, 204, 1952.

Raw rubbers are assumed to obey the fluidity power law, $\phi = fr^{n-1}$, ϕ = fluidity, r = shearing stress, $n > 1$. For 3-dimensional flow, the generalized law is assumed to be $\phi = gW^{(n-1)/(n+1)}$, where W = rate of energy dissipation. It is shown that this law is equivalent to Nadai's 3-dimensional law of steady creep, expressed in terms of the octahedral shearing stress and octahedral rate of shear. On the basis of the fluidity power law, laws of extrusion are derived for circular and slit tubes and orifices, surface slip also being included in the analysis. By dimensional analysis a general theorem is established concerning the effects of stress (or pressure) and apparatus dimension on deformation and flow rates. Exptl. data, obtained with circular tubes of various lengths and diameters and covering a 100-fold range in extrusion rates, agree roughly with the power form of the derived extrusion laws, but do not give the expected values of the exponent n in some cases. Surface slip was too small to measure in the present expts. B.C.R.A.

2620. Strain-hardening and softening with time in reference to creep and relaxation in metals.

A. NADAI. *Trans. Amer. Soc. Mech. Engrs.*, **74**, 403-13 (April, 1952).

Analytical expressions are formulated for describing the influence of strain-hardening, of the time rate of change of the flow resistance, and of recovery strains on the creep and relaxation of metals under uniaxial stress. SCI. ABSTR.

2621. Creep and recovery of a mineral glass at normal temperatures.

S. PEARSON. *J. Soc. Glass Technol. (Trans.)*, **36**, 105, 1952.

Measurements have been made of the creep and recovery of a soda-lime-silica glass over the temp. range 20°-80°C. The deformation of the glass can be divided into three parts: (1) An instantaneous elastic strain; (2) A Newtonian viscous flow at constant rate, which is not recoverable; (3) A delayed elastic strain, which develops slowly according to a decay function of time and which is completely recoverable. The viscosity at 20°C. is 2.5×10^{20} poises, and the viscosity varies with temp., over the temp. range used for

the tests, according to the relation $\eta T = Ae^{\frac{H}{RT}}$ in which H , the activation energy, is 4,300 cal/mol. The ratio of the max. delayed elastic strain, c , to the elastic strain, a , is a constant at a given temp., and is approximately equal to 0.0025 at 20°C. The temp. dependence

of the ratio, over the range of temp. used for the tests, can be represented by an equation of the form $\frac{c}{a_T} = Ae^{\frac{-H}{RT}}$ in which H is not significantly different, being 4,100 cal/mol.
B.C.R.A.

2622. Structure and properties of filled rubber mixtures. IX. Change in carbon black structure during repeated deformations (In Russian).

K. PECHKOVSKAYA, T. S. MIL'MAN AND B. DOGADKIN. *Koll. Zhur.*, 1952, **14**, 250.

2623. The viscous flow of glass at low temperatures.

I. PEYCHÈS. *J. Soc. Glass Technol.*, 1952, **36**, 164.

2624. The essentials of fluid dynamics.

L. PRANDTL. *London and Glasgow, Blackie and Son* (1952), 452 pp.

A comprehensive survey of the whole field of fluid dynamics, including hydrostatics, perfect fluid flow, laminar and turbulent motion of viscous incompressible fluids, and compressible fluid flow. Physical arguments are used whenever possible in presenting the theory, and complicated mathematical analysis is avoided. Experimental results are described with many photographs and diagrams, and applications to hydraulics, aeronautics and meteorology are included. References to original papers throughout.

SCI. ABSTR.

2625 Theory of a rotation-vibration viscosimeter for highly viscous liquids.

L. S. PRISS. *Zh. tekhn. Fiz.*, **22**, No. 6, 1050-61 (1952) (In Russian).

The theory is further developed of the rotation-vibration viscosimeter suggested by Shvidkovskii for melted metals. It follows from the theory that the method can be used for liquids with high kinematic viscosity, particularly for slags. Formulae and tables are given. The method has been verified on aqueous solutions of glycerol.

SCI. ABSTR.

2626. Tests in the casting of clays and ceramic bodies and the measurement of fluidity. I.

P. RENAULT. *Industr. Céram.*, No. 429, 56, 1952.

This work concerns the suitability of various clays, kaolins, and ceramic bodies, for casting. It aims at putting at the disposal of ceramists a method of testing more practical and more complete than the old methods, which depend too much on the personal judgment of the operator. The article describes a number of tests, the old methods and the new, with their advantages and disadvantages.

B.C.R.A.

2627. Investigations of spontaneous shortening of rubber. I. On the theory of spontaneous shortening (In Russian).

M. M. REZNIKOVSKIĬ AND M. K. KHROMOV. *Koll. Zhur.*, 1952, **14**, 177.

Various dash-pot/spring models illustrate the theory. Relaxation and internal friction are studied. (Little original in theory).

G.W.S.B.

2628. Investigations in the field of Rubber Vulcanization. XI: Effect of Degree of vulcanization on internal friction of unfilled rubbers from Butadiene-sterol rubbers. (In Russian).

M. M. REZNIKOVSKIĬ, V. S. YUROVSKAYA AND B. A. DOGADKIN. *Koll. Zhur.*, 1952, **14**, 444.

A pendulum impact apparatus ascribed to V. L. Biderman (? Biedermann) is used. "Internal Friction" is calculated from heat losses.

G.W.S.B.

2629. The (plastic) flow curve and the elastic after-effect.

M. I. ROZOVSKIĬ. *Zh. Tekhn. Fiz.*, **22**, 880-2 (No. 5, 1952) (In Russian).

Starting with the Volterra integral relation for stress (1931), it is shown that the curvature of the plastic flow region of the deformation-load curve obtained in a tensile

test depends only on the coefficients of relaxation and after-effect for the material. It is assumed that, when load is increased suddenly in equal steps and at equal time intervals, the stress-strain relation is linear when the time intervals are sufficiently long for the deformation to cease, and non-linear when the loads are applied whilst the deformation still goes on, as shown by Ivanov's experiments (1948). SCI. ABSTR.

2630. On the theory of fluids.

G. S. RUSHBROOKE AND H. I. SCOINS. *Proc. Roy. Soc. A.*, 1953, **216**, 203.

2631. Hysteresis in viscosity in the critical region.

V. K. SEMENCHENKO AND E. L. ZORINA. *Doklady Akad. Nauk. S.S.S.R.*, 1952, **84**, 1191.

The binary systems nitro-benzene-hexane and triethylamine-water are studied. The hysteresis of viscosity manifests itself in repeated measurements. Near the crit. concentration the effect is less pronounced than in mixtures showing slight opalescence.

2632. Density, expansivity, and viscosity, of molten alkali silicates.

L. SHARTSIS, S. SPINNER AND W. CAPPS. *J. Amer. Ceram. Soc.*, **35**, 155, 1952.

The densities and viscosities of melts in the systems $\text{Li}_2\text{O}-\text{SiO}_2$, $\text{Na}_2\text{O}-\text{SiO}_2$, and $\text{K}_2\text{O}-\text{SiO}_2$ were measured with a restrained-sphere apparatus over the temp. range $1,000^\circ-1,400^\circ\text{C}$. At the higher temps. in this range the density in each system decreased with increasing alkali content. On a molecular basis the thermal expansivity of the K silicates was greater than that of the Na and Li silicates. Comparisons on the basis of molecules of alkali per unit vol. of glass showed that to a first approximation the viscosity of the systems investigated was almost independent of the kind of alkali ion involved.

B.C.R.A.

2633. A contribution to mechanics of hardened mortar.

K. SHINAHARA. *Reps. of Res. Inst. of Appl. Mech. Japan.*, 1952, 1, No. 1, 9.

The relations between compressive, bending, tensile and shearing strengths of various mixes are estimated from experimental results. E.W.J.M.

2634. The third virial coefficient in polymer solutions.

W. H. STOCKMAYER AND E. F. CASASSA. *J. Chem. Phys.*, 1952, **20**, 1560.

With the aid of approximate models for the intermolecular potential energy, the third virial coefficient Γ_3 in the virial expansion for the osmotic pressure of a dilute polymer solution has been determined as a function of the second coefficient and one additional parameter obtainable from intrinsic viscosity or light scattering measurements. The theory and experimental results agree in indicating that the ratio Γ_0/Γ_2^2 for most solutions is markedly less than the value of $\frac{5}{8}$ given by the hard sphere molecular model proposed by others for the estimation of Γ_3 . The limitations are discussed under which light scattering may be used for evaluation of the virial coefficients. AUTHORS.

2635. The hardness of metals.

D. TABOR. *Oxford, Clarendon Press: London, Oxford University Press* (1951) ix + 176 pp.

Review in *Nature (London)*, **170**, 818, Nov. 15, 1952.

SCI. ABSTR.

2636. The measurement of the absolute viscosity of anomalous fluids. I. The measurement of the time-dependence of viscosity of thixotropic materials.

S. THORNTON. *Proc. Phys. Soc. B.*, 1953, **66**, 115.

2637. II. A comparison of absolute viscosity measurements on instantaneously thixotropic fluids.

S. THORNTON AND D. RAE. *Proc. Phys. Soc. B.*, 1953, **66**, 120.

2638. **The absorption of water by hair, and its dependence upon applied stress.**
L. R. G. TRELOAR. *Trans. Faraday Soc.*, 1952, **48**, 567.

2639. **On similarity (conditions) in flow of visco-plastic liquids (In Russian).**
N. V. TYABIN. *Koll. Zhur.*, 1952, **14**, 270.

As a new criterion of similarity, author proposes numeric $A = \frac{\theta}{\xi v^2}$. (θ is tensor of critical shear stresses, v is velocity, ξ is density). For visco-plastic materials, the most important numerical criterion is B , given by the sum of A and the reciprocal of Reynolds number (Re). Under steady flow conditions author proposes equation $Eu = f(B, G)$ where Eu is Euler number $\equiv \text{pressure} \div \xi v^2$ and G is a kind of extension factor. For laminar flow, there are two equivalent criterial equations $La = f(I_1)$ and $I_2 = f(I_1)$ when La is the Lagrange number $\equiv Eu \times Re$ ($I_1 = Re/A$; $I_2 = Eu/A$). I_1 is called the "Il'yushin Criterion."

Turbulent flow is characterized by the Euler number (Oldroyd's work is quoted). "The similarity principle, applied to the study of rheological processes, does not permit the integration of the complex differential equations of flow, but determines criterial equations; and, after experimental investigation, leads to a complete account of rheological similarity." G.W.S.B.

2640. **The viscosity of vitrous selenium from 0° to 100°.**

K. ÜBERREITER AND H. J. ORTHMANN. *Koll. Z.*, 1951, **123**, 84.

2641. **Measurements of viscosity of synthetic slags rich in ferrous oxide.**

G. URBAIN. *J. Chim. Phys.*, 1952, **49**, 308, 316.

An oscillating concentric viscometer suitable for use at 1000–1450°C. is described. Experimental results for the systems $FeO-SiO_2$ and $TiO_2-FeO-SiO_2$ are given.

2642. **Structure and properties of mixtures of filled synthetic rubbers. VIII. Toughness of mixtures of filled synthetic rubber produced directly from latex (In Russian).**

R. UZINA AND M. DOSTYAN. *Koll. Zhur.*, 1952, **14**, 197.

Quantitative studies of effects of carbon and bentonite fillers.

G.W.S.B.

2643. **Some effects of variations in temperature on the firmness of Cheddar cheese.**

W. G. WEARMOUTH. *Dairy Industries*, 1952, **17**, 994.

The sphere hardness tester shows marked effects of temperature changes. These changes are reversible. A needle penetrometer using three standard bitumen-testing needles, is also illustrated. G.W.S.B.

2644. **Effect of shear temperature on viscosity in a rotational viscometer measurement.**

R. N. WELTMANN AND P. W. KUHN. *J. Colloid Sci.*, **7**, 218, 1952.

A method is described which permits determination of the approx. temp. distribution over the cross-sectional area of a Newtonian material that is subjected to shearing forces in a rotational viscometer. By correlating the change of viscosity to temp. increases, and by determining the actual viscosity value as found in the rotational viscometer, the effect of thixotropy can be studied. Temp. calculations with regard to an Oronite polybutylene oil and a silicone fluid have been made, in each case for various operational conditions of a rotational viscometer. It appears that, in some instances where previously the presence of thixotropy was suspected, temp. increases might be responsible for viscosity break-down. In other instances, thixotropic behaviour must still be postulated to explain the exptl. results. B.C.R.A.

2645. **Application of Eyring's rate equation to viscometer data on paraplex.**

H. B. WHITFIELD AND T. BARON. *J. Coll. Sci.*, 1952, **7** (3), 268.

2646. **The viscosity of urea solutions of keratin.**

E. F. WOODS. *Aus. J. Sci. Res. A. Physical Sciences*, 1952, 5 (3), 555-562.

The viscosity-concentration relationships for wool dispersed in concentrated urea solutions are comparable with those reported for globular proteins in urea.

The axial ratios calculated from the viscosity increments by means of the Simha equation, using the assumption of unhydrated prolate ellipsoids as molecular models, vary from 9.9 to 16.3, these values depending on the buffer ion present, the conditions of equilibration, and the concentration of urea. There appears to be a slight change in configuration to a more spherical molecule on removal of salts from the urea solutions and on reduction of the urea concentration.

AUTHOR.

2647. **Oscillations by kinetic friction.**

C. ZOCCHI. "*ATA*," *Naples*, 1952, No. 11.

The author considers that jerky motion by a series of "stick-slips" is an indication of relaxation oscillations. He believes that "intermittent wear" has an effect on these oscillations. In his discussion of the electrostatic component of the force of friction he seems to overlook the experimental fact that no jerky motion is experienced with metallic friction elements when severe tearing takes place.

R.S.

BOOK REVIEW

"Psychological and Psychophysical Studies of Craftsmanship in Dairying."

R. HARPER

Brit. J. Psychol. Monogr. Suppl. No. 28
Camb. U.P. 1952

Except for a short period during the war, the (British) National Institute for Research in Dairying has been engaged for the past fourteen years in psychophysical research into the methods by which craftsmen, especially cheese-makers, assess and control rheological conditions in their materials.

Dr. Harper gives a brief summary of the earlier part of this work, but his book deals mainly with his own contribution during the four years in which he was engaged in this research. During this time he was able to clarify and develop Scott Blair and Coppen's earlier work and more especially so to improve statistical techniques that the tests could be shortened, thus eliminating a number of obscuring effects produced by fatigue and boredom. He also developed the study of individual subjects as distinct from taking grouped data as had previously been done.

One of the most interesting features to the rheologist is Harper's demonstration that a skilled and highly motivated subject can assess differences in firmness of rubber-like materials by handling, with an order of accuracy at least as high as that reached by many test machines. But "firmness" as judged subjectively, is a unitary experience, involving a synthesis of the separate physical aspects of the materials and their behaviour. Harper showed that Scott Blair's attempt to deal with this situation by the use of fractional differentials fits the facts but it has not yet been possible to verify quantitatively the calculated value for the fractional order of differentiation without reference to psychophysical data.

In a sense, the book is a companion volume to Miss Baron's Monograph, reviewed in Bulletin 35, which deals with mechanical testing. Each will be better appreciated if read in conjunction with the other.

G.W.S.B.

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