

BRITISH RHEOLOGISTS' CLUB



Hon. Sec.:

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Hon. Editor:

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CLUB NOTES.

Future Meetings.

The next meeting of the Club, co-operating with the S.W. Branch of the Chemical Society, will be held in Exeter on Friday, May 16th, followed by a visit to the St. Austell Clay workings in Cornwall on the following day. Details will be circulated in due course. The speakers on the 16th will be: 2.15 p.m., Dr. G. Nagelschmidt; 4 p.m., Dr. H. H. Macey. Members are asked to inform the Hon. Secretary by May 3rd if they wish accommodation reserved.

A visit has been arranged to the Forest Products Research Laboratories at Princes Risborough on Saturday, June 7th. Only a limited number of members can be included in this visit.

Plans for the Annual Conference to be held in Manchester in September (10th—13th approx.) are well advanced. A meeting in Newcastle-on-Tyne on Wednesday, October 15th, has been arranged jointly with the Society of Chemical Industry and the Oil and Colour Chemists' Association.

List of Members.

In future, printed lists of members with their addresses and interests will be circulated to members at the start of the financial year, following the Annual Conference and Annual General Meeting. In the meantime, lists of new members will be included in the *Bulletin*.

German Testing of Plastics.

Dr. H. R. Lang has kindly drawn our attention to a Report on tests on plastics developed by the I.G. Farben during the war. The Report is entitled "Plastomers, Notes on Testing," Brit. Intell. Objective Sub-Committee, Report No. 968, and is obtainable from H.M. Stationery Office.

Summer School on Mechanical Properties of Solids.

Members of the Club are invited to attend a Summer School on the Mechanical Properties of Solids, followed by a Conference on the Strength of Solids, to be held at the H. H. Wills Physical Laboratory, Bristol, from July 2nd-9th, 1947.

Applications and enquiries should be addressed to the Director of the Department of Adult Education, The University, Bristol 8.

New Members since December, 1946.

- BEARD, MR. S. G. .. Firwood, 54 Edison Avenue, Romford.
Interests: Carbon black suspensions, thixotropy and viscosity methods.
- ELLIOTT, MR. W. S. .. Delanium Ltd., 140 Battersea Park Road, London, S.W. 11.
Interests: Carbons, graphites, coals and coke. Tests of hardness and brittleness.
- OLDROYD, MR. J. G. M. Messrs. Courtaulds, Ltd., Research Laboratory, Maidenhead, Berks.
Interests: Theoretical rheology. High polymeric substances in rayon industry.
- RIGDEN, MR. P. .. 50 Church Road, West Drayton, Middlesex.
Interests: Bituminous road surfacing materials. Tensile and compression tests.
- TAYLOR, MR. J. S. .. c/o Richard Taylor & Sons, Ltd., Buchanan Road, Liverpool, 9.
Interests: Wheat flour doughs, reconstituted cream fillings, tin greasing agents; Dough consistency.
- WESTBROOK, MR. E. L. E. c/o Building Research Station, Bucknall's Lane, Garston, Watford, Herts.
Interests: Putties, mastics and general methods of testing.
- SOPER, MR. A. K. .. Research Laboratory, Kodak Ltd., Wealdstone, Middlesex.
Interests: Gelatin and similar materials. Pigment dispersion. Particle size analysis. Consistometers.
- SUMNER, DR. C. G. .. 15, Goddington Lane, Orpington, Kent.
Interests: Foods, especially cereals.
- GRODZINSKI, MR. P. .. Industrial Distributors (1946) Ltd., Diamond Research Department, 32-34, Holborn Viaduct, London, E.C. 1.
Interests: Hardness testing. Diamond, Sapphire, sintered carbides.

Change of Name:

- MISS J. TOOGOOD (on her marriage), to MRS. HOLDEN Braeside, Ridgemoor Road, Englefield Green, Surrey.

The Rheological Studies of Sir George Beilby, 1900 to 1921.

Those interested in flocculation and thixotropy will find it refreshing to re-read the account of Beilby's elegant experiments recorded in his papers and his book, *Aggregation and Flow of Solids* (Macmillan, 1921) which experiments, as he said, "filled all my spare hours most pleasantly." He defines rigidity as being that fundamental property of the solid state resulting from the molecular structure, energy being required to alter the fixed relations between the particles, and he considers that the indefiniteness of meaning of "hardness" which is often used synonymously with rigidity is partly due to the fact that it is most frequently used as a term of comparison. The property of cohesion is regarded by Beilby as the most fundamental endowment of matter; his micro-photographs of small particles of zinc dust, gold filings, etc., hanging in chains and clusters from glass and metal surfaces, are very

convincing evidence of the force of adhesion between fine solid particles. Beilby was satisfied that the adhesion was not electric in origin nor due to liquid films, and he computed that the force of attraction was of the order from 1 to 23 tons per square inch. From these experiments he concluded that the open packing of powders was due directly to these cohesive forces, the particles adhering at the points of contact.

In experiments (1903) when the flocculation in water suspension of fragments of calcium carbonate and silver chloride films were watched, Beilby found that "the pellicules dart about with Brownian movement. If two spicules have an encounter they at one coalesce and the enlarged unit proceeds to fresh encounters till its mass becomes so large that it sinks to the bottom as a granule and rests there. Its power of absorbing other spicules having increased with its mass, it now acts as a centre of attraction to the still active spicules which play around it with swift to and fro movements ultimately darting into it and being absorbed. Attraction was seen to take effect at a distance of 25 to 30 μ . Smaller particles do not come to rest at the first point of contact but move around as if to settle in a firmer contact."

From his aggregation experiments he was led to consider the open structure of thin metal films such as those of gold and silver and of oxide and sulphide films on metals; these films he found to be amorphous and granular and, with frosted silver films, granules of diameter 100 μ were present. The transparency of the films was attributed to open formation and confirmed by the enormously reduced electrical conductivity and their high absorption of liquids: he writes, "one of the central facts . . . is that the molecules of a pure substance can be assembled in aggregates which possess widely different degrees of mobility in response to heat or to mechanical disturbance. The contrasted qualities of the hardness and softness, of rigidity and mobility must therefore be intimately associated with the ultimate molecular structure of the aggregate . . . with the more rigid form of aggregation, the vitreous, the molecules are in a state of elastic strain, as indicated by loss of electrical conductivity and by the impairment of the elasticity under the acoustical test."

From the study of thin films, Beilby arrived at his most important conclusion, namely, that a crystalline solid can, by mechanical disturbance, be made to pass through an intermediate liquid state into a vitreous or non-crystalline state. This solid-liquid-solid transformation he observed with a great variety of substances, repeated in a variety of ways. The polishing of speculum metal or the rubbing of a calcite crystal with the finger was sufficient to liquify the surface layer and alter its character to a depth of about 1 μ .

He wrote, "a crystalline solid can by mechanical disturbance be made to pass through an intermediate liquid state into a vitreous or non-crystalline state. . . . A freedom of movement has been conferred on the molecules which enables them to behave like liquid molecules; freedom lasts only so long as the molecules are moving over each other under the action of the polishing agent. When the movement ceases, we must assume that the freedom also ceases, but not before the molecular attraction has drawn the surface into a continuous covering skin comparable in smoothness with the surface of a liquid . . . the furrowing of calc spar rubbed by leather experiments indicate it is equally certain that the surface can only close over and mask the effects of the furrowing if it has been in a state of complete fluidity for a measurable depth and for a finite period after the externally caused movement has ceased."

Beilby observed the bridging effect over pits, flaws and scratches by the liquid surface layers during rubbing and polishing with metals, crystals, glass and other materials.

After establishing the solid-liquid-solid thixotropy with materials at surfaces he indicates its practical significance. He points out for example that in tabloid and briquette making the production of liquid layers under pressure will cause the cementing of the particles into a solid mass, and although the stropping of a razor will cause flow at the edge with a consequent sharpening and hardening, yet to cause "mass flow" a pressure of hundreds of tons per sq. inch is required. He considers the flow of metals, marble and other rocks is consequent upon the liquid-like flow which occurs at all the surfaces of slip. The liquid provides the lubricant which makes the slipping possible while the immediate re-solidification of the liquid films provides the cement which bonds the deformed crystals into a structure of greatly increased rigidity. He wrote, "I believe that the phenomenon of crystalline flow is of universal application and that its effects will yet be traced in new and unexpected directions."

Beilby continued his researches shewing that thixotropy was not confined to surfaces. He found, for example, that when he bruised barium platinocyanide crystals lightly with the rounded side of a pestle the yellow crystals liquified to a brown liquid which solidified to the brown vitreous state on release of the pressure. Working outdoors in Adelboden in Switzerland at temperatures of -10°C . he found that small pellets of vitreous ice liquified under the pressure of a steel burnisher, the pressure being far short of the hydrostatic pressure which would be required to lower the m.p. to that temperature. The flowed material resolidified to the fully crystalline state. From these and similar experiments he came to the conclusion that the flow of glaciers cannot be explained entirely by the hydrostatic pressure change on melting.

He extended his experiments with pellets to other materials, such as gold, antimony, etc., and found that these could be temporarily liquified by pressure given by a drop hammer weighing a few ounces falling through a foot. He wrote, "antimony is one of the most brittle and fragile of the common metals yet it can be made to behave as any malleable substance would."

E.W.J.M.

RHEOLOGY ABSTRACTS

520. Methods of Representing the Properties of Visco-elastic Materials.

T. ALFREY. *Quart. Appl. Maths.* **3**, 143 (1945).

Discusses the mathematical relations between the elements in a Voigt or Maxwell model and a visco-elastic material in pure shear.

R.L.B. (*vide* abstr. 304 and 305).

521. The Rigidity of Thixotropic Systems.

R. AMIOT. *Comptes Rendus, Acad. Sci.* **224**, 388, 1947.

Measurement of the rigidity of flocculating sols of iron hydroxide has been made using the well-known wire-torsion method.

The relation between rigidity, concentration and time of flocculation has been expressed by the empirical equation :

$$\mu = k c^m \theta^n \text{ where } \mu \text{ is the rigidity,}$$

c the concentration and θ time in minutes.

E.W.J.M.

522. A Method for Obtaining Stress-strain Relations in a Non-Isotropic Flexible Sheet Material, under two Dimensional Stress.

S. L. ANDERSON. *J. Scientific Inst.* **24**, 1, 1947.

Two cylindrical envelopes are made, one of them having the first principal direction of the material circumferential and the second with this longitudinal and these are stressed by the application of internal pressure. Strain measurements are made in axial and circumferential directions. The results are combined with those obtained from the material under simple tension.

H.C.T.

523. Study of Ocean Swell.

N. BARBER and F. URSELL. *Nature*, **159**, 205, 1947.

A comparison of spectra of a long series of wave observations made on the N.W. Cornish coast, compared with the meteorological charts of the North Atlantic, shows that the swell arriving from a distant storm shows a more or less narrow band of periods, the minimum period of which decreases with time, in a manner which is consistent with the assumption that the swell travels from the generating area to the coast with a velocity equal to the classical group velocity appropriate to the period on arrival. Low swell was received in Cornwall from a tropical storm off the coast of Florida (2,800 miles distant), and a storm near Cape Horn (6,000-7,000 miles distant).

E.W.J.M.

524. Viscometric Investigation of Dimethylsiloxane Polymers.

A. J. BARRY. *J. Appl. Phys.* **17**, 1020, 1946.

The intrinsic viscosities of a series of linear methyl polysiloxanes, (repeating unit Me_2SiO), have been determined in toluene solution. These values have been correlated with molecular weights determined chemically, and by osmotic and light-scattering methods. The Staudinger equation was found to be applicable only up to molecular weights (M) of 2500 ; for the higher polymers the dependence of intrinsic viscosity on number average molecular weight could be expressed by the formula :

$$[\eta] = 2.10^{-4} M^{0.66}$$

The bulk viscosities of the polymers showed a dependence on M agreeing with Flory's formula.

L.R.G.T.

525. The Theory of Axisymmetric Turbulence.

G. K. BATCHELOR. *Proc. Roy. Soc. A*, **186**, 480, 1946.

An invariant theory is developed. The form of the fundamental velocity correlation is obtained and scales of axisymmetric turbulence are defined. Equations are established giving the rates of change of the mean squares of the velocity components, involving two terms. The first represents viscous dissipation, the second a transfer of energy from one component to the other. This is due to the finite correlation between the velocity and pressure at neighbouring points. The effects of this correlation and of this viscous dissipation on the two velocity components are examined, and expressions are obtained for the rates of change of the mean squares of the vorticity components.

SCI. ABSTR.

526. Conservation of proper-mass. The notion of a perfect fluid.

O. C. DE BEAUREGARD. *C.R. Acad. Sci., Paris*. **222**, 271, 1946.

The paper contains a brief summary of certain mathematical theorems on the motion of a fluid in its 4-dimensional aspect. An incompressible fluid is defined. When the force 4-vector is the gradient of a scalar, the motion of the fluid may be such that along lines and tubes of flow the velocity 4-vector is irrotational. [See abstr. No. 420.]

SCI. ABSTR.

527. Natural Modes of Vibration of Simple Frames.

S. BENNON. *J. Franklin Inst.* **234**, 13, 1947.

Although it is possible to obtain approximate natural frequencies for a frame by the application of Rayleigh's method, this method becomes rather difficult for the higher modes of vibration. The Rayleigh method consists essentially of the determination of the equivalent lumped parameters of a system with distributed parameters. This equivalence is established for a configuration of the system approximating that existing during actual vibration. The natural frequency is then determined for the equivalent lumped system.

To obtain an accurate solution for all of the modes of vibration, however, it is necessary to recognise the distributed nature of the parameters and to solve the appropriate differential equation. This type of analysis has been made for a simple beam (1, 4) and for a beam on many supports (2, 3, 4). It is the purpose of this paper to illustrate the application of this form of analysis to simple frames by considering the individual sides as simple beams with the proper end conditions. Solutions are derived for rectangular and triangular frames. Frequency curves and vibrational modes are illustrated for the first two modes of whose sides have the same distributed parameters. The equilateral case is considered in detail due to certain singularities which appear. Finally, the applicability of the results to certain general types of frames is indicated.

M.W.T.

528. The Anisotropy of Thermal Expansion as a Cause of Deformation in Metals and Alloys.

W. BOAS and R. W. K. HONEYCOMBE. *Proc. Roy. Soc. A*. **188**, 427, 1947.

Plastic deformation produced by repeated heating and cooling of certain non-cubic metals has been studied from -190 to 250°C . The extent of the deformation which results from the anisotropy of thermal expansion of individual crystals becomes greater as the temperature range is increased. In the case of Cd. plastic deformation was detected even after 20 cycles over the temperature range $30-75^{\circ}\text{C}$.; in cyclic treatment to higher temperatures the deformation was associated with extensive grain-boundary migration. Cyclic treatment of Sn, Cd and Zn between room temperature and that of liquid air resulted in complex slipping and twinning,

but grain-boundary migration was practically absent. Cooling from the liquid state, which represents half a thermal cycle, sets up stresses in metals possessing anisotropy of thermal expansion, and leads to plastic deformation. This is shown by the detection of slip lines and grain-boundary accentuation in certain cast non-cubic metals. In Cd, subsequent annealing results in marked grain growth. Experiments were carried out with a series of Sn-rich Sn-Sb alloys, the majority consisting of the Sn-rich matrix in which particles of a hard second phase of cubic crystal structure were embedded. It was found that the deformation in the region of the boundaries between crystals of the two phases was considerably smaller than in the region of the crystal boundaries of the anisotropic matrix. Similar results were obtained with Sn-base bearing alloys. SCI. ABSTR. (*vide* abstr. 427).

529. The Flow of Gases in Pipes at Low pressures.

G. P. BROWN, A. DiNARDO, G. K. CHENG and T. K. SHERWOOD. *J. Appl. Phys.* **17**, 802, 1946.

Data are presented on the flow of air at low pressures in copper pipes of radius 0.795 and 1.30 cm.; iron pipes of radius 2.64, 5.12, and 10.1 cm.; and for hydrogen in a copper pipe of radius 1.30 cm. Data are also given for the resistance to flow of air in 1½- and 3-inch nominal pipe size elbows, for 1½-inch Kinney bellows valves, and for short sections of 1-inch nominal pipe size iron pipe connecting large gas chambers. The data on straight iron and copper pipes, together with the data from the literature on glass capillaries, are correlated by the introduction of a correction factor *F* in Poiseuille's equation. *F* is correlated graphically in terms of a dimensionless group representing the ratio of mean free path to pipe radius, with separate curves for iron pipe and for copper and glass pipes or capillaries. AUTHORS' ABSTRACT.

530. The Physics of Adhesion.

N. A. DE BRUYNE. *J. Scientific Inst.* **24**, 29, 1947.

Adhesion may be classed as specific or mechanical and, of the factors influencing the former, that of wetting is the most important preliminary to obtaining a sound joint. It is a sign of intermolecular attractive forces, namely primary forces due to ionic or covalent bonds and secondary a "van der Waals" forces: the latter being the most important.

The residual strains, flow under clamping pressure and the nature of strains under external forces as well as the effect of the joint form are considered. H.C.T.

531. Kinetic Friction in or near the Boundary Region. I. Apparatus and Experimental Methods.

B. CHALMERS, P. G. FORRESTER and E. F. PHELPS. *Proc. Roy. Soc. A.* **187**, 430, 1946.

An apparatus of the sphere-against-flat scribing tool variety is described. An annular plate was made the driven specimen, and three hemispherical specimens placed at the corners of an equilateral triangle and fixed in a rigid holder formed the restrained friction element. If the normal force is applied at the centre of this triangle, which is also made the centre of rotation of the driven specimen, then each hemispherical specimen carried one-third of the normal load, and, assuming the coefficient of friction to be the same in each case, the tilting and translational forces acting on the specimen-holder are balanced. The three hemispherical specimens were placed at slightly different distances from the centre so that their tracks did not coincide.

The support of the annular plate was acted upon by a worm drive from an electric motor through a gear box supplying either of five speeds: 0.0096, 0.0328, 0.122, 0.526 and 2.26 cm./sec. The disk carrying the annular friction element is

wound internally with an electrical heating element, enabling temperatures up to about 150° C. to be obtained.

The force required to restrain the hemispheres is measured by balancing against a variable dead load, instability being suppressed by fluid damping.

A sensitivity of 2% is claimed for this apparatus. If a number of tests are made with the same materials but with the friction elements re-prepared by the same method for each experiment, results may differ by 10% or more, possibly owing to the difficulty of obtaining similar surface finishes with successive re-preparations.

R.S. (*vide* abstr. 541).

532. Movement of a Liquid Between Two Concentric Spheres.

F. CHARRON. *Comptes Rendus Acad. Sci.* **223**, 1098, 1946; **224**, 373, 1947.

The author has observed the movement of coloured globules, the same density as the liquid, when the inner suspended sphere was allowed to rotate by means of a thread. The movement depends considerably on the viscosity of the liquid and the trajectories are complicated.

Globules remain in the same hemisphere in which they were originally placed.
E.W.J.M.

533. The Influence of Electric Potentials upon Friction. II. Clays; Equilibrium Responses.

R. E. D. CLARK. *Trans. Farad. Soc.* **42**, 456, 1946.

The experiments here described would appear to indicate that, in the case of strongly anisotropic particles suspended in water, an upward rise in the friction/voltage curve followed by a fall is connected with the presence of balance ions on the suspended particles. An immediate fall in friction is caused by the orientation of particles at the sliding surface. A subsequent rise—in the range 2–4 volts—only occurs when the particles are conducting. The conductivity of particles, at right angle to their plane, is also responsible for the previously described rectification of current between a “moving” and a stationary electrode.
B.R.R.A.

534. Investigation of the Wood and Smith Effect.

N. N. DAVIDENKOV and M. N. TIMOFEEVA. *J. Tech. Phys., U.S.S.R.* **16**, 283, 1946.

For the purpose of investigating the theory of residual variation in the parameters of the crystal lattice after uniform plastic deformation, as propounded by Wood and Smith, experiments were carried out for measuring the residual strain in the surface layers of plastically distended samples, consisting of sheet Al and sheet duralumin plated with Al. Measurements were taken on one surface of the specimen, pre-treated with NaOH solution. No sign of residual strain was observed in seven series comprising: basic tests on Al specimens; tests in which caustic soda treatment was confined to an area down the centre of the specimen surface; samples having various grain size; tests with different thicknesses of layer removal; investigation of the influence of caustic treatment on the mechanical properties of the surface; samples subjected to thermal treatment in vacuum; and experiments for investigating the influence of tempering temperature on the uniformity of the specimen properties throughout its thickness. A further series of tests for checking the method on non-uniform specimens of duralumin plated with Al confirmed the initial assumption. The conclusion is drawn that the residual parameter variation claimed by Wood is either a characteristic of the crystallite or arises from the specific condition of the experiment.
SCI. ABSTR. (*vide* abstr. 101).

535. Combined Tensile and Bursting Tester.

W. C. DILLON & Co. INC. *Paper Ind. & Paper World*. **28**, 1220, 1946.

The Dillon Low-Range Tester has been designed primarily for determining the tensile strength of materials within the range of zero to 100 lb. but which can also be used for making bursting strength determinations. The dial of the test incorporates four separate capacities: 0-10 lb. in 1 oz. dial divisions; 0.25 lb. in 2 oz.; 0-50 lb. in 4 oz.; and 0-100 lb. in 8 oz. Accuracy of the tester is given by the manufacturer as $\frac{1}{2}$ to 1%.

P.A.T.R.A.

536. The Determination of Jelly Strength in Absolute Units.

R. B. DREW. *J. Oil & Col. Chem. Assoc.* **29**, 259, 1946.

A simple apparatus of the torsion type, based on Schwedoff's work (*Ann. Physik*, 1904, (iv), **14**, 139) is described which can be used for comparative jelly strength determinations and which will give results in absolute units which are roughly comparable with the Bloom instrument. It can also be used for preliminary research work over a wide range of concentrations and temperature. The reproducibility is of the order of 1 to 5% depending on the strength of the jelly.

P.A.T.R.A.

537. Viscometric Studies of Chemical Equilibria.

C. DRUCKER. *Ark. Kemi. Min. Geol.* **22 A** (No. 6) *Paper* 21, 1946.

Simple relationships between the viscosity of a fluid and its purely static properties are now investigated, for which purpose the internal frictions of non-electrolytes and of strong and weak electrolytes have been measured at 25°. The strong electrolytes afforded data quantitatively in accord with the Jones-Falkenhagen formula. A formula corresponding to this, but considering the dissociation of incompletely dissociated electrolytes, has been confirmed. The frictional effect of semi-electrolytes in completely dissociated and in entirely undissociated conditions has been calculated from the data found; from that effect it has been found possible to derive the degree of dissociation in final concentration. The dimery constant derived from the internal friction was found to be in agreement with the value derived from the volume effects. The course of the concentration/intrinsic viscosity relation is closely related to that of the partial specific volume.

SCI. ABSTR.

538. The Stiffness of Paper.

E. EFTRING. *Svensk Papperstidn.* **49**, 169, 1946.

The stiffness of paper and paper board is determined by a new method: one end strip of paper 30 mm. wide is fixed between two brass clamps and the free end is placed on an edge, 30 mm. distant from the grip. The edge is attached to the threads of one leverage arm of a Sartorius' moderating analytical balance. The other side of the balance is loaded with a suitable weight, for newspaper 30 mg. and the change in equilibrium by this 30 mg. is determined. From this change the elevation of the edge (about 0.5 mm.) and the increase of the power on the bottom side of the strip are calculated. From these figures the stiffness (power in mg./elevation of the edge in mm.) and the stiffness modulus K_d are estimated. The error is generally smaller than 5%; the bending is 90% reversible. Results from determinations of stiffness of various papers (17 to 250 g./sq.m.) containing sulphite, sulphate and mechanical pulp are tabulated. From these tables the effect of variations of different factors is evident.

P.A.T.R.A.

539. Colloid-chemical Studies on Skim-milk.

H. EILERS and J. KORFF. *Ministry of Agriculture and Fisheries (Dutch) Bulletin* No. 50 (15) G, 1945.

The bulletin consists of four papers, of which the last two only are rheological.

In the third paper, a careful study is made of the voluminosity of skim-milk. The Smoluchowski "electro-viscous" term is incorporated in the voluminosity constant. Eilers' "rheological concentration" concept is also introduced. Skim-milk deviates very slightly from Newtonian behaviour.

When the acidity of skim-milk is artificially varied, it is found that the natural pH corresponds to minimum viscosity. The effects of pasteurisation and other heat treatments are studied.

In the last paper of the series, studies are made on the rheology of "evaporated" and "condensed" milk (the latter further condensed than the former and with sugar added).

The slow rise in consistency which occurs in condensed milk on keeping and the increases in voluminosity induced by heating are discussed.

Data are quoted from both capillary and rotation (MacMichael) viscometers.

G.W.S.B.

540. **Impact Testing of Adhesives.**

A. H. FALK. *Bull. Amer. Soc. Test. Mater.* **141**, 42, 1946

A description is given of a testing machine based on the principle of the falling ball test for plastics, but adapted to the requirements of bonded or glued specimens. Details of the preparation of test specimens, and test results for a number of adhesives, are included.

SCI. ABSTR.

541. **Kinetic Friction in or near the Boundary Region. II. The Influence of Sliding Velocity and other Variables on Kinetic Friction in or near the Boundary Region.**

P. G. FORRESTER. *Proc. Roy. Soc. A.* **187**, 439, 1946.

With the apparatus described in Part I, measurements were made with various combinations of friction elements under "dry" conditions, and with lubricants applied either by deposition from a dilute solution in redistilled petroleum ether, or by adding excess lubricant and polishing off first with degreased cotton-wool, and then with several changes of degreased polishing cloth.

The coefficients of friction are recorded at the five testing speeds, and it appears that there are certain cases where the coefficient of friction appears to decrease with increasing speed of relative motion and other cases in which there does not seem to be any dependence between the coefficient of friction and the speed of relative motion, whilst there are a few cases in which the coefficient of friction appears to increase slightly with the speed of relative motion. The author's discussion of his results in the absence of data bearing on the validity of Amontons' law offers difficulties. Without applying any lubricant the coefficients of friction are of the order of 0.3; in the presence of lubricants they are as a rule below 0.2.

R.S. (*vide* abstr. 531).

542. **Viscosities of the Di-hydroxybenzenes and some of their Derivatives.**

J. N. FRIEND and W. D. HARGREAVES. *Phil. Mag.* **37**, 120, 1946.

Viscometers of the Oswald type were used to determine the viscosities, at various temperatures, of the following substances: *o*-, *m*- and *p*-dimethoxybenzene, *o*-, *m*- and *p*-methoxyphenol, *o*- and *m*-dihydroxybenzene and 2-nitroresorcinol. Viscosity-temperature curves are drawn. The results are used to discuss some features of molecular structure and equilibrium, especially hydrogen bonding.

SCI. ABSTR.

543. **Rheological Properties of High-viscosity Solutions of Long Molecules.**

F. H. GARNER and A. H. NISSAN. *Nature*, **158**, 634, 1946.

The macromolecules of a strained elastic solid depart from their most probable form with a consequent decrease in entropy. In a liquid, the groups of molecules

have freedom to increase their entropy by moving to regions of less strain. Experiments are described in which this tendency is demonstrated: (1) Abnormally high surface tension of expanding jets; (2) Abnormally high "inlet pressure loss" in pipes leading from reservoirs; (3) Apparent increase of viscosity with radial distance for flow in pipes; (4) "Secondary flow" phenomena depending on the space derivatives of the rate of strain, rather than of the strain or stress themselves. SCI. ABSTR.

544. Viscosities of Pure Hydrocarbons.

J. M. GEIST and M. R. CANNON. *Ind. Eng. Chem. (Anal.)* **18**, 611, 1946.

Determinations of the viscosities of a large number of hydrocarbons at three different temperatures are reported. A relative accuracy of 0.1 %, and an absolute accuracy of 0.5 % is claimed for the data. L.R.G.T.

545. The Behaviour of Glass under Impact and Static Loading.

R. N. HAWARD. *Phil. Mag.* **36**, 777, 1945.

Experiments were made on the strength of glass beams and plates; the beams being tested by slow loading and by the impact of a pendulum, and the squares both by pressing a steel ball against the square and by the impact of a falling ball. In the case of slow impact, using objects much heavier than the glass, the energy required to break the glass is greater than that needed under static conditions. This is explained by considering the time changes in the modulus of rupture of the glass. But as the velocity of impact is increased, the energy required to shatter a glass plate diminishes rapidly. When glass is broken by small balls at high velocities characteristic cone or "shell" fractures are produced, and these seem to be an extension of the statically formed ring cracks along lines perpendicular to the maximum tension in the glass. Photographs of actual fractures are given. SCI. ABSTR.

546. Instrumentation Studies. LV. Determination of the Bonding Strength of Paper. Institute of Paper Chemistry. I. Progress Report on the Development of a New Method.

Paper Trade J., **123**, 24, 26, 28 (Oct. 31); 24, 26, 28, 30, 32, 34 (Nov. 7), 1946.

Various methods for the direct measurement of the strength of the bond between the surface and the body of a sheet are subject to errors such as those originating in penetration of the sheet structure by the adhesive, modification of the sheet by elevated temperatures where the adhesive requires heating, and strongly varying stress due to non-uniform thickness of paper. Accordingly, a method has been developed in which a tensile stress is applied by means which are relatively free of these errors. In the new apparatus the tensile stress arises in a viscous film in a manner simulating the actual printing operation in a rotary press. The apparatus, which is described in detail, consists essentially of a pair of steel wheels or rollers having finely ground surfaces which carry films of known and constant thickness of a viscous oil of known viscosity (blown castor oil, viscosity 0.3 to 3.0 kilopoises). These wheels are caused to roll over test specimens under a known load with uniform but continuously variable speed. The speed of the wheels, which is accurately measured by means of an electric speed meter, is varied until that speed at which rupture occurs is determined. Descriptions of techniques and such auxiliary equipment as the viscometer, film-forming devices, and speed meter are given. The critical speed is defined as that above which the test specimen suffers an open rupture. At speeds slightly below critical, coated papers exhibit a "blistering," which is caused by internal failure. As the speed is increased to the critical speed, the blisters become more extensive and open up, small bits of the surface adhering to the surfaces of the wheels. At speeds appreciably greater than the critical speed, the rupture is complete and general, large areas being carried away by the wheels. A critical

speed is arrived at most quickly by approach first from below, then from above. Investigation of the relationship between critical speed and viscosity for constant bonding strength shows that, within experimental error, the product (velocity) $\times$ (viscosity)=constant. This produce (designated V.V.P.) is taken as a measure of bonding strength. In a special series of samples in which the casein content of the coatings varied from 10 to 12%, the V.V.P. varied from about 12 to 95 kp.cm./sec. When the film thickness was varied from 0.0020 in. to 0.0008 and 0.0004 in. two interesting phenomena were observed. At the greater film thickness the V.V.P. of specimens having coatings containing 10, 14 and 18% casein was nearly a constant. At the smaller film thicknesses there were large differences between the V.V.P. of these three specimens. When the film thickness was 0.0020 in., the failure of the sample containing the least casein occurred in the body stock rather than between the coating and body stock. At the smaller film thicknesses, only the coating of this sample was removed. The observations indicate that (a) the V.V.P. is reasonably related to casein content in a coated sheet and would probably serve as a useful measure of bonding strength; (b) local stress intensification is of greater importance in a thin film than in a thick film, in which the stress is so designed as to slide freely down the rod were constructed. The energy level of the blow is governed both by the weight of the ring and the height of the fall. Among the test results tabulated are the number of blows required to effect a failure at a given energy, applied to the testing of Buna-N rubber base adhesives. The adhesive is intended for all types of bonding, particularly metal to metal. These are four references. P.A.T.R.A.

547. Deformation of an Ice Layer under Travelling Loads.

K. E. IVANOV, P. P. KOBEKO and A. R. CHULJMAN. *J. Tech. Phys., U.S.S.R.* **16** 257, 1946.

Vibrations in the ice layer with the passage of motor vehicles were investigated on Lake Ladoga, the Neva and Lake Suzdal. Deformation measurements carried out by means of Reynov yield record rs provided continuous records of displacement of the ice layer relative to the bed over a wide area. For vehicle speeds of 5 to 15 km./hr., simple elastic deformation was observed, the disturbance advancing and retreating along the ice at the vehicle speed. The yield in this case was $\frac{2}{3}$ to $\frac{1}{2}$ of that for static loading. At vehicle speeds above 20 km./hr., a wave vibration was initiated in the ice, extending over a distance of hundreds of metres; for an ice thickness of 60 cm. and water depth 5 m., the wavelength was 200 m. and speed of propagation $v \approx 35$ km./hr., independent of vehicle speed and weight. This speed is roughly $\frac{1}{100}$ th that of acoustic waves in ice, and is nearer that of travelling waves in water, as calculated from the Lagrange formula (25 km./hr.). Vibrations in the ice layer are presumably caused by the hydrodynamic wave, the deviation from the Lagrange formula being a function of the ice layer. The formula relating speed of propagation of the waves under ice, with modulus of elasticity (E), ice thickness (d) and water depth (H) is given as:

$$v = \sqrt{gH \left(1 + \frac{\pi^4 E d^3}{24 \gamma l^4} \right)}$$

where γ is the weight of the liquid per unit volume. An analysis of load conditions provides recommendations for the regulation of traffic over the ice crust. SCI. ABSTR.

548. Plastic Deformation and Viscosity of Ice.

P. P. KOBEKO, N. I. SHISHKIN, F. I. MAREI and N. S. IVANOVA. *J. Tech. Phys. U.S.S.R.* **16**, 263, 1946.

Tests were carried out on Lake Suzdal and lakes near Leningrad, in tanks dropped into openings in the ice, diameters being 3, 4 and 8 m., water-depth 3 m. and air

temperatures -5 to -10°C. , with uniform ice thicknesses from 1 to 10 cm. Ice temperatures were brought to 0°C. by applying a covering of snow. Continuous records of the yield of the ice layer were obtained under static loading. Measurements were also taken on the natural 40 cm. ice crust on Lake Suzdal, the load being applied by filling a 5 m.^3 water tank resting on the ice. Elastic deformation is illustrated by data for small loads (to 1 200 gm.) on a 0.49 cm. ice layer. The radius of elastic deformation appears as a function of layer thickness, and is independent of the load. Comparative data are given for plastic deformation over periods up to 100 min., and, in some tests, up to 8 days. The curves show deformation as a function of distance from the point of application. Deformation proceeds linearly with time, except for ice temperatures below 0°C. Elastic deformation comprises 0 to 5% of the overall deformation. For a 40 cm. layer, elastic deformation affects a radius of 25 m., and plastic deformation 5 m. The data are examined on the basis of several formulæ, which are given. Safe limits for stationary loads are calculated.

SCI. ABSTR.

549. **Wetting and Strength of Adhesion.**

P. P. KOBKO, and F. I. MAREI. *J. Tech. Phys., U.S.S.R.* **16**, 277, 1946.

De-icing problems are studied on the basis of an experimental investigation on a number of wetting combinations (copper-mercury, copper-mercury amalgam, copper-water, glass-water and iron-water) and non-wetting combinations (glass-mercury, iron-mercury and polystyrol-water). Results obtained from the first seven combinations show that the strength of adhesion on freezing is not a function of the type of material or liquid, or of the wetting character of the combination. Values of approximately 20 kg./cm.^2 were obtained throughout, except for the polystyrol-water combination, for which a value of 2.2 kg./cm.^2 was obtained. On adding a wetting reagent, complete wetting was obtained, but the strength of adhesion remained unchanged. Similar behaviour was observed with other plastics (polymethyl methacrylate, ebonite and escapon) and varnishes. Plastics and varnishes in combination with non-crystallising liquids such as engine oil provided adhesion strengths around 20 kg./cm.^2 . Hence methods for countering icing by the application of coatings are discounted.

SCI. ABSTR.

550. **Theory of the Method of Measurement of the Viscosity of Liquids by Blowing-off the Liquid Layer in a Narrow Wedge-shaped Slit.**

M. KUSAKOV. *Acta Physicochim. U.R.S.S.* **20**, 47, 1945.

Based on the solution of the problem of laminary flow of a viscous fluid through a capillary, the cross-section of which is a sector of a circle, a more precise representation is given of the hydrodynamic principles of the blow-off method for the case of a narrow wedge-shaped slit. The accuracy with which the "blow-off force" (for small apex angles of the wedge) can be considered proportional to the distance from the slit edge is determined.

SCI. ABSTR. (*vide* abstr. 473).

551. **A Characteristic of the Mechanical Properties of Liquids obtained by Blowing-off Radially a Liquid Layer in a Narrow Plane-parallel Slit.**

M. KUSAKOV and K. KRIM. *J. Exp. Theor. Phys.* **16**, 266, 1946

The method gives information on the rheological properties of liquids such as lubricating oils.

SCI. ABSTR.

552. **Volume Flow of Plastic Materials.**

A. R. LEE, M. REINER and P. J. RIGDEN. *Nature, Lond.* **158**, 706, 1946.

A specimen of asphalt was found to increase in volume by 2% while undergoing a linear extension of 7% under constant load. The fractured surface after breaking was rough, in contrast to the smooth appearance of an impact fracture. SCI. ABSTR.

553. **Plastic Flow, Creep, and Stress Relaxation. I. Plastic Flow.**
C. MACK. *J. Appl. Phys.* 17, 1086, 1946.

Plastic substances are considered to be composed of units of flow with various yield values. It is shown that in this case the product of the strain rate and viscosity is equal to the sum of the differences between the applied stress and the yield values. This relationship can be applied to any plastic system free of elastic after-effect and expresses their mechanical properties in terms of a coefficient of viscosity which is independent of the stress applied. With the proper choice of the distribution of yield values any kind of relation between stress and strain rate can be established. This relationship is applied to plastic flow which is defined as a deformation mechanism having a curvilinear relationship between stress and rate of deformation and a constant rate of deformation at constant stress. Equations are given for the coefficient of viscosity of such systems and for the relaxation of stress at constant deformation as a function of time. AUTHOR'S ABSTR.

554. **Plastic Flow, Creep, and Stress Relaxation. II. Creep.**
C. MACK. *J. Appl. Phys.* 17, 1093, 1946.

The general equation covering the deformation of plastic substances given in Part I is applied to creep. Creep is defined as a mechanism of deformation for systems which have a curvilinear relationship between stress and strain rate and a curvilinear relationship between strain and time at constant stress. Creep is connected with changes in the internal structure of a plastic substance and results in an increase in strength of such materials through work-hardening. Equations are derived which give the stress as a function of strain rate and time (time-hardening) as a function of strain rate and strain (strain-hardening), and as a function of strain rate, strain, and time. The difference between time-hardening and strain-hardening is discussed. Expressions are given for the coefficients of viscosity of such systems which are independent of the stress applied. The relaxation of stress at constant strain is discussed, and it is shown that the stress relaxation depends upon the history of the substance under test. The concept of creep is also applied to thixotropic systems which are considered as cases of work-softening. AUTHOR'S ABSTR.

555. **Plastic Flow, Creep, and Stress Relaxation. III. Creep and Elastic After-effect.**

C. MACK. *J. Appl. Phys.* 17, 1101, 1946

A large number of substances show the phenomenon of elastic after-effect, and part of their deformation recovers on unloading as a function of time. This portion of the deformation at constant stress has a strain rate which decreases with time and is, therefore, comparable to creep. Expressions are given for the strain-time relationships of such systems, and the process of stress-relaxation at constant strain is discussed. The equations given in connection with plastic flow, creep due to work-hardening, thixotropy, and creep in combination with elastic after-effect are applied to data given in the literature, and it is shown that these equations suffice to describe the deformation and relaxation mechanisms of a variety of materials such as metals, clay soil, food products, acrylic acid polymeride, polyvinyl chloride, cellulose acetate, manila ropes, paper laminates, phenolic moulding compounds, rubber, asphalt, and bituminous pavements. AUTHOR'S ABSTR.

556. **Two Phase, Two Component Flow in the Viscous Region.**

R. C. MARTINELLI, J. A. PUTNAM and R. W. LOCKHART. *Trans. Amer. Inst. Chem. Engineers.* 42, 681, 1946.

Measurements of the flow times of fuel oils—air mixtures through a glass tube, diameter approximately 1.5 mm., are given together with various tentative relationships. The results were compared with flow through porous material. E.W.J.M.

557. Fluid Motion Between Parallel Planes. Dynamical Stability.

D. MEKSYN. *Proc. Roy. Soc. A.* **186**, 391, 1946

The equations of motion lead to a 4th order differential equation containing a large parameter. This has two slowly varying, non-viscous integrals and two rapidly varying, viscous integrals. The solutions are used to obtain these results, U being the velocity of the mean motion: (1) The region where U is equal to the wave velocity is the source where vibrations are generated; slowly varying vibrations give rise to large, rapidly varying vibrations in passing through the critical point. (2) Curved profiles admit a periodic motion at very high Reynolds numbers. (3) Parabolic flow is unstable at high Reynolds numbers. The critical Reynolds number is $R = U_0 h/\nu = 6\,700$, and the corresponding wavelength is about $3 \times$ the width of the channel. Here U_0 is the mean velocity at the axis, and h is the $\frac{1}{2}$ -width of the channel.

SCI. ABSTR.

558. Stability of Viscous Flow Between Rotating Cylinders. I.

D. MEKSYN. *Proc. Roy. Soc. A.* **187**, 115, 1946.

The equations of motion are integrated by deriving asymptotic expansions for the velocities, in terms of a large parameter, λ . Only the case where the cylinders rotate in the same direction is considered. The final formulæ are simple and Taylor's conclusions are confirmed. In the case of instability, if the angular velocities Ω_1 and Ω_2 are proportional to $\cos \lambda z$, $e^{\sigma t}$, then λ approximately satisfies $\lambda d = \pi$, where d is the distance between the cylinders. It is shown that if Ω_1 is fixed there is only a limited number of possible wavelengths, and probably only a single wavelength can be observed. There are no solutions when σ is complex.

SCI. ABSTR.

559. Determination of the Yield Value of Plastic Systems by the "Withdrawal" Method.

R. METROT. *Revue Inst. Fr. du Pétrole*, **1**, 78, 1946.

The treatment of plastic systems by the withdrawal method consists of the evaluation of the shear stress, exerted by a body when pulled out of a plastic material. It is particularly suitable for investigations in the region where there is no or very little actual flow.

The author investigates clay suspensions which are classified into non-thixotropic suspensions and thixotropic gels according to their response to the withdrawal method. Investigated are the yield value as a function of concentration (2 diagrams), its recovery after agitation (2 diagrams) and its variation with age (1 diagram). The measured yield values range from about 10 to 500 dynes/cm². Suggested applications include drilling muds, greases, printing ink, paint and similar material. L.A.S.

560. The Mechanical Properties of Metallic Solid Solutions.

F. R. N. NABARRO. *Proc. Phys. Soc., Lond.* **58**, 669, 1946.

The theoretical relation between the lattice strains produced by precipitation in a metal and the corresponding increase in hardness is extended to the case of lattice strains in metallic solid solutions. The elastic limit of a single crystal of a solid solution is calculated on the assumption that the crystal will slip when the applied external stress is equal to the mean value of the internal stress. This mean is taken over the length of a dislocation, assumed to be 1,000 atoms. The estimate agrees in order of magnitude with the experimental observations. Similar considerations are applied to the hardness of polycrystalline solid solutions. The theory is extended to cases in which the increase of hardness produced by alloying is not large in comparison with the hardness of the pure solvent.

SCI. ABSTR.

561. Adhesivity and its Measurement.

B. PERSOZ. *Peintures, pigments, vernis*. **21**, 162, 1945.

The definitions recently adopted for the words "adhesivity" and "adherence" are given. The former alone possess a physical significance; adherence is a complex and arbitrary property that is a function of the method of measurement. Normal and tangential adhesivity are detected on samples of film detached from the surface. The technique for conducting such measurements is described. Factors affecting adhesivity are film thickness, degree of drying, pigments and condition of the surface.

P.A.T.R.A.

562. General Theory of Adhesion. Symposium on Adhesives.

R. C. RINKER and G. M. KLINE. *Symposium on Adhesives. Res. Assoc. Brit. Rubber Manufrs. Summary Current Lit.*, **24**, 467 1946.

A discussion is given of the nature of cohesion, with examples of cohesion within several materials, such as metals, wood and natural and synthetic high polymers. Theories of the nature of adhesion are summarised. Further sections deal with the mechanism of absorption and the nature of adhesion to various materials, such as adhesion to metals, to woods, to glass, to rubber, to plastics. The last section deals with the properties of adhesively bonded structures. There are 27 references.

P.A.T.R.A.

563. Mechanical Principles of the Screw Extrusion Machine.

Z. ROGOWSKY. *Inst. Mech. Engrs.* Preprint, 1946.

The screw extrusion machine as used in the plastics industry is briefly described and submitted to a dimensional analysis resulting in generalised relations between, on the one hand, pressure developed, rate of discharge, and drive-power and, on the other, viscosity of plastic extruded, speed of machine, and a characteristic dimension. The velocity distribution of an assumed ideally viscous, so-called "plastic," material within a rectangular screw thread is determined, and expressions for discharge and pressure developed are derived in terms of its dimensions. These expressions are used to discuss the effect of increasing the number of "starts" on a screw. A method of rating extrusion machines is proposed so as to allow an adequate description of their capacities.

B.R.R.A.

564. Extension of Griffith's Theory of Rupture to Three Dimensions.

R. A. SACK. *Proc. Phys. Soc.* **58**, 729, 1946.

Griffith's treatment of the problem of rupture is extended to materials containing circular cracks in their interior. The condition for spreading of a crack (i.e. rupture) is determined by considering the contributions to the total free energy of the system due to (a) the elastically stored energy and (b) the surface tension. It is found that the tensile strength of a brittle material in one direction is not affected by stresses at right angles to it. The results differ from those of Griffith by a factor lying between 1.57 and 1.81.

L.R.G.T.

565. On Plastic Bodies with Rotational Symmetry.

C. H. W. SEDGEWICK. *Quart Appl. Maths.* **3**, 178, 1945.

Carries further Hencky's analysis, finding lines of principal stress and of maximum shearing stress.

R.L.B.

566. The Distribution of Stress in the Neighbourhood of a Crack in an Elastic Solid.

I. N. SNEDDON. *Proc. Roy. Soc. A.* **187**, 229, 1946.

A crack in an infinite 2-dimensional elastic body is considered, and the body is

deformed by the opening of the crack under the action of a uniform hydrostatic pressure acting over its surface. Expressions for the stress components and for the principal shearing stress are derived from Westergaard's solution of the elastic equations [*J. Appl. Mech.*, **6**, 49 (1939)]. Some numerical results are given. The case of a circular crack, in 3 dimensions, is analysed, in a cylindrical polar co-ordinate system, by the method of Hankel transforms. The stress distribution in the case where the applied internal pressure remains constant over the entire surface of the crack is considered in detail. The stress components are calculated at various points of the elastic body, and sets of tables allow the values at intermediate points to be obtained by interpolation. The principal shearing stress is also tabulated and the contours of equal principal shearing stress are plotted to show the distribution of stress near the crack.

SCI. ABSTR. (*vide* abstr, 498, 499).

567. Viscosity of Solutions of Salts.

G. SUTRA. *C.R. Acad. Sci., Paris*. **222**, 875, 1946.

—The equation of Darmais for the viscosity, η , of solutions of salts is of the form $(\eta - \eta_0)/\eta_0 = AC^i + BC + \dots$, where η_0 is the viscosity of H_2O , A , B , etc., are constants, and C is the molar concentration of the solution. $B = 0.0015 v$, where v is the volume of the ions (in $\text{\AA}^3$) given by one molecule of the salt. This is in general agreement with experiment, but there are discrepancies for $MgSO_4$, $MnSO_4$ and $CdSO_4$. It is shown that the disagreement is due to the fact that these electrolytes, supposed to be strong, are far from being completely dissociated in 0.0005M. solution. In fact, they may even be associated in solutions of this concentration.

SCI. ABSTR.

568. Stress-optical Properties of Rubber.

L. R. G. TRELOAR. *Nature*, **159**, 231, 1947.

A treatment of the optical properties of strained rubber, assuming the links of the molecular chain to be themselves optically anisotropic, has been developed for general homogeneous strain. Using a sheet of pure gum natural rubber swollen in paraffin to about twice its original volume stretched in two perpendicular directions in such a way as to produce a homogeneous strain, the author has shown that the bir fringence in a principal plane is proportional to the difference of the principal stresses, and to the difference of the squares of the principal extension ratios. With dry rubber, Hooke's law was not obeyed in shear and neither the molecular theory nor Mooney's theory accounted quantitatively for the experimental data, though Mooney's theory provided the closer approximation.

E.W.J.M.

569. Sea Waves.

P. J. H. UNNA. *Nature*, **159**, 239, 1947.

Notes on secondary waves, tidal streams and shore breakers.

E.W.J.M.

570. Flow of a Plastic-viscous Body Between Two Parallel Plane Walls and in the Annular Space Between Two Coaxial Pipes.

M. P. VOLAROVICH and A. M. GUTKIN. *J. Tech. Phys., U.S.S.R.* **16**, 321, 1946.

The Bingham differential equation describing the flow of a plastic viscous body for tubes of circular section can be extended to tubes of rectangular section by assuming one side of the rectangle to be several times greater than the other. The problem is thus considered as that of the flow of a plastic mass between two parallel plane walls (plane capillary). Practical application occurred in the peat-drying process. An analogous problem, arising in the development of a new press, is represented by the flow of the plastic mass in the annular space of two coaxial pipes, which is here considered as an annular capillary. Equations are developed for the two cases, which are shown to be basically identical.

SCI. ABSTR.

571. The Effect of Temperature on the Strength and Fatigue of Glass Rods.

B. VONNEGUT and J. L. GLATHART. *J. Appl. Phys.* **17**, 1082, 1947.

By the use of an electrodynamic quick-loading device, the strength of scratched soda-lime glass rods was measured at various temperatures between -190°C and 520°C for load durations of 0.1 second, 10 seconds and 100 seconds. It was found that the strength was highest at the lowest temperature, declined to a minimum at $100^{\circ} - 200^{\circ}\text{C}$, and then increased for higher temperatures. Static fatigue was exhibited at all temperatures, being maximum in the region of minimum strength. Comparisons with the results of other experimenters are made. AUTHORS' ABSTR.

572. Symposium on Adhesion and Gluing. VI. The Factors Determining the Adhesion of Gummed Paper.

L. DE WEERD. *Chem. Weekblad.* **39**, 118, 1942.

Better adhesion of gummed paper to certain types of cardboard can be obtained by addition of wetting agents to the gum or moistening the paper. The use of Nekal BX, 2% of which was added to the "gum" consisting of 12 g. per sq. m. of a gelatin-dextrin mixture was found beneficial. Addition of filler to the paper also helps to promote sticking of the adhesive. It appears that poor adhesion is often caused by insufficient moistening of the paper by the wetted gum. P.A.T.R.A.

573. The Drag of Cylinders in Fluids at Slow Speeds.

C. M. WHITE. *Proc. Roy. Soc. A.* **186**, 472, 1946.

Experiments were made with Cu wires falling sideways in glycerine solutions of various viscosities. When the speed, s , is very small the resistance is independent of the density of the fluid when this is finite in extent. The motion is purely viscous and the boundary distance controls the pattern; Reynolds number is unimportant. When s is greater, the resistance is independent of the distance and agrees with Lamb's formulae for a cylinder in an infinite fluid. The experiments cover a range of Reynolds numbers from 10^{-5} to 100. At a low speed the influence of distant boundaries is great and Lamb's formulae is not applicable, e.g. when the Reynolds number is 10^{-4} the presence of boundaries 500 diameters away doubles the drag.

SCI. ABSTR.

BOOK REVIEWS.

Design and Construction of Concrete Roads.

By R. A. B. SMITH, M.C., A.M.Inst.C.E., and T. R. GRIGSON, O.B.E., M.Inst.C.E.
Second edition. Concrete Publications, Limited, 14, Dartmouth street, London, S.W.1.
[Price 8s. 6d. net.]

Since the appearance, in 1934, of the first edition of this deservedly popular text-book, the theory and practice of road construction, in common with other branches of engineering, have made considerable progress; in particular, the rapid development in the use of machinery and experience gained during the war years with American specialised plant have more or less revolutionised the technique of concrete-slab construction. Undoubtedly, the publication of this new edition is a timely and welcome addition to literature on the subject. The book, which has been almost completely rewritten, is essentially a practical treatise. It opens with a chapter on the siting and planning of new roads, in which the main principles are briefly described and the latest Ministry of Transport recommendations, enumerated. A later chapter deals with junctions, curves and super-elevations in a similar manner, and includes a number of excellent diagrams and tables.

The excavation and preparation of the foundation, the design of road slabs, reinforcement, joints and formwork are all dealt with in detail in separate chapters and the first-mentioned subject is copiously illustrated by photographs of various modern types of machines. In general, the treatment is sound, and the recommendations—for example, those for different classes of slab, types and spacing of joints, etc.—have been chosen as representative of good present-day practice in this country. Notes on the latest theories and trends are also included. The section on joints is as clear and comprehensive an exposition of the subject as we have seen in any text-book. The observations on drainage of a clay subsoil are open to some criticism, however, for the possible effect of cross drains on the supporting power of the road bed is not made clear; also, while a minimum gradient of 1 in 400 may be satisfactory from an engineering point of view, the possible accumulation of water at the kerbs, and consequent splashing of pedestrians by passing vehicles, should not be overlooked.

The middle portion of the book is devoted to constructional practice, useful information being given on concrete materials and proportions, mixing, placing and finishing concrete, coloured roads and labour outputs. The illustrations in these sections, and, indeed, throughout the whole of the work, deserve special mention for their clarity and for the obvious care with which they have been selected. The treatise concludes with chapters on maintenance and repair, concrete haunches, concrete foundations, and cement-grouted roads. The technique of cement grouting as applied to road and slab construction has been attracting increasing interest in recent years and the fact that a full chapter has been devoted to it is indicative of the up-to-date character of this concise and informative volume.

Review, *Engineering*, Jan. 3rd, 1947.

The Journal of Glaciology. Vol. I. No. 1. June, 1947.

The Journal of Glaciology is published by the British Glaciological Society. This Society and re-formed and re-named at the end of the war from the old "Association for the Study of Snow and Ice." The Journal is well produced and no doubt it will take its place in the field of British journals that are regularly studied throughout the scientific world.

Men like Tyndall and Forbes from these islands first went out into the field to make quantitative observations on glacier motion. Their studies took the form of

academic enjoyment associated with holidays amidst the fascinating mountain scenery in the Alps and elsewhere, and their writings contributed considerably to our knowledge of these mountain areas. Ever since these early days, a small school of glacial adventurers has persisted and their studies have gradually assumed fundamental and economic importance. It is not surprising therefore that this journal, the only one in the world devoted entirely to Glaciology, should be published in a country which does not possess a single glacier.

The glacier is probably the most obvious of Nature's experiments in Rheology, and no doubt the study of glacial motion will provide useful analogies with the flow of other less picturesque materials in daily use.

The article of chief interest to rheologists is that by Gerald Seligman on Extrusion Flow in Glaciers. Recent observations on a Swiss glacier suggest that at certain vertical sections the maximum flow velocity does not occur at the surface but at a point much nearer the rock floor. This is what is meant by extrusion flow, and the hypothesis is supported by many eminent glaciologists. Glacier motion has been a topic for discussion ever since the scientist first set eyes on the phenomenon. All arguments are normally based on surface observations and progress will only be made when deep observations become available.

W. H. WARD.