

BRITISH RHEOLOGISTS' CLUB

BULLETIN No. 19



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ROYAL AIRCRAFT ESTABLISHMENT,
FARNBOROUGH, HANTS.

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CLUB NOTES.

International Rheological Congress.

The Hon. Editor wishes to apologize for a foolish error in calculating the cost of board and lodging in Holland. By an oversight, only one full meal per day was allowed for!

Future Meetings.

By the time this Bulletin reaches members, the Summer Meeting of Watford will have taken place.

It is planned to hold our Annual General Meeting this year in London 29th October and to combine this meeting with a Discussion on "Fracture." A meeting on Oil Refining is also planned for the Autumn, to be held in Birmingham.

Among other future meetings it is hoped to include :

" Mathematics and Rheology " (London).

" Biological Aspects of Rheology " (Cambridge),

and a joint meeting with the Chemical Society and Royal Institute of Chemistry in Exeter, early May, 1949, on Suspensions and Sedimentation.

Bulletin No. 20.

Because of the International Congress in September, the next issue of the Bulletin is likely to be a little late for Press. Members are asked to excuse this as unavoidable.

The (American) Society of Rheology.

The attention of members is drawn to the special " Rheology Issue " of the Journal of Colloid Science (vol. 3, No. 2), in which it is announced that a Committee has been appointed to administer the Award in Rheology inaugurated in memory of Professor E. C. Bingham. In addition, we are informed that the new journal, " Physics To-day " will publish, from time to time, rheological news of general interest such as has previously appeared in the " Rheology Bulletin."

In the same number, E. K. Fischer gives a " Note on the Origin of the Term ' Rheology ' " in which he points out that Forel defined " die Rheologie " as early as 1901 as the study of flowing surface water such as springs, brooks, streams and rivers (Handbuch der Seenkunde, J. Engelhorn, Stuttgart, 1901).

The remaining articles in this " Rheology Number " will all be of interest to members. It is with much regret that we learn that the article by Henry Green is posthumous. His contributions to rheology are well-known to British readers, and we offer our sympathy to our American colleagues in their loss.

Postscript. The Hon. Editor has received a letter from Dr. Earl K. Fischer informing us that the American Society of Rheology is holding a meeting at the Hotel Pennsylvania, New York, from November 5th to 7th. Dr. Fischer very kindly invites any British Rheologists who may be able to attend, and is good enough to say that the American Society would welcome a contribution from anyone who is able to go.

The Polytechnic, Regent Street, W.1.

A course of eight lectures on the Rheology of Metals will be given by M. W. Thring, M.A., F.Inst.P. and P. Feltham, B.Sc., A.Inst.P., of the British Iron and Steel Research Association, on Tuesday evenings from 7.00 to 8.30 commencing 5th October, 1948.

Also a course of about twenty-five lectures on Theoretical Rheology will be given by I. Berenblut, M.Sc., A.R.C.S., A.Inst.P., on Wednesday evenings from 7.30 to 9.00, commencing 29th September, 1948.

Details may be obtained on application to Dr. J. Topping.

Clay Minerals Group of the Mineralogical Society.

A series of meetings is to be held during August this year in connection with the International Geological Congress. A subject for discussion will be Geology and Mineralogy of Clays.

Appointment Vacancy.

A British Firm has a vacancy in their Technical Development Laboratory for a Physical Chemist to undertake research work on the fundamental physical properties of Titanium Pigments, with particular reference to crystal size, shape and distribution, optical properties, and rheological characteristics. The post offers an excellent opportunity for a young man who has a flair for precise physical measurement and who is not afraid to develop new techniques in the fine particle field. Previous industrial experience is not essential, but he must have a good Honours Degree in Physics or Chemistry, preferably followed by research experience in the physico-chemical branch of science. A five-day week is operated by the Company, and the salary offered will lie within the range depending on age, qualifications and experience. Applications, which will be treated in strict confidence, should be addressed to the Hon. Editor.

News of Members.

DR. B. CHALMERS has been appointed Head of the Metallurgy Division of the A.E.R.E. at Harwell.

MR. C. DIAMOND has left Messrs. Courtauld's and is in practice as a Private Consultant.

DR. H. FRÖHLICH has been appointed to the Chair of Theoretical Physics at the University of Liverpool.

DR. R. LESSING has been elected Chairman of the Technical Committee of the Executive Council of the National Smoke Abatement Society.

DR. AND MRS. C. A. MAUNDER FOSTER are on their way to South Africa. Dr. Maunder Foster writes: "Although we shall be over 6,000 miles away from the

centre of activities, we can readily appreciate the fellowship and common interest which brings together in a friendly manner people of so many diverse outlooks and interests."

PROF. M. REINER hopes to come to England in the near future for a period of one or two years.

DR. K. WEISSENBERG is leaving the Shirley Institute to take up work with the Rayon Research Association.

Note.—The Hon. Editor would be grateful if members would keep him informed of changes of address and occupation as well as of any other information likely to be of interest to members.

Finance.

For certain reasons it was not possible to present the Annual Statement of Accounts for last year in complete and audited form at the Annual General Meeting. The final statement as accepted by the Hon. Auditor is therefore printed below :—

ANNUAL ACCOUNTS, 1st OCT., 1946, to 30th SEPT., 1947.

Receipts :

							£	s.	d.
Subscriptions.	..	..	..	..	..	..	259	0	0
Donations	..	..	..	..	..	..	2	18	0
Receipts re 1946 Conference	..	..	..	..	..	..	117	16	11
Receipts re 1947 Conference (on account)	..	..	..	..	..	..	70	0	0
Royalties	..	..	..	..	..	..	5	16	3
Book Sales	..	..	..	..	..	..	17	6	
							456	8	8
Balance—brought forward	..	..	..	..	..	..	53	11	4
							£510	0	0

Expenses :

							£	s.	d.
Stationery and Printing	..	..	..	..	..	..	105	6	5
Postage	..	..	..	..	..	..	20	16	0
Honoraria (Office help)	..	..	..	..	..	..	56	14	0
Expenses, 1946 Conference	..	..	..	..	..	..	110	1	6
Expenses, 1947 Conference	..	..	..	..	..	..	100	0	0
Expenses—other meetings	..	..	..	..	..	..	4	18	6
Sundries	..	..	..	..	..	..	5	5	0
							£403	1	5

							£	s.	d.
Cash at Bank	..	..	..	..	..	..	104	16	3
Petty Cash	..	..	..	..	..	..	2	2	4
							106	18	7
							£510	0	0

This is to certify that I have compared the above statement of Receipts and Expenses with the Club's books and find it to give a correct record of the Club's financial position for the year ended 30th September, 1947.

(Signed) V. G. W. HARRISON,
28th May, 1948.

New Members.

Chief Interests.

- Mr. F. J. Bailey
Messrs. Ilford Ltd.,
Central Engineering Dept.,
Ilford, Essex.
- Mr. R. W. Money,
The Laboratories,
Messrs. J. Lyons & Co.,
149 Hammersmith Road,
London, W.14 .
- Mr. P. Thirion,
Institut Français du Caoutchouc,
42, rue Scheffer,
Paris XVI^e.
- Mr. J. W. Amner,
28 Pembroke Avenue,
Surbiton.
Surrey.
- Viscometry and gel formation.
- Rubber-like material.
- Lubricating grease and allied products ;
yield-values and viscosity.

Additions to B.R.C. Library.

" Rheology in relation to pharmacy and medicine," by Dr. G. W. Scott Blair.
London : The Pharmaceutical Press.

" The Flow of suspensions—thixotropy and dilatancy " by John Pryce-Jones. Proc. University Durham Phil. Soc.

" Volume Hysteresis in the swelling of gels " by Dr. W. W. Barkas, D.S.I.R.

CORRESPONDENCE

Dear Sir,

I have noticed a letter from Dr. J. D. Morgan on page 4 of your March " Bulletin."

Dr. Morgan cites the stiction of a plug valve which has been allowed to stand; a similar instance occurs in the difficulty encountered in starting a railway train from rest. I agree with Dr. Morgan that the main journal pressure is in neither case likely to be sufficient to force out the residual monomolecular film. However, I consider that this is not the full story ; owing to the imperfections of the surfaces the contact which is established resembles that which would occur at the collision of two planets, both with mountainous surfaces. Here the contact would occur only over the crests of hill ranges, i.e., over a very small fraction of the total area. The pressures at these points would greatly exceed the mean pressure ; similarly with the journals the pressure at the small area at the point of contact evidently suffices to exclude the lubricant, and probably results in local seizure : this will account for the high starting effort required.

Turning now to Dr. Morgan's other point, it seems that the difficulty which he observes in maintaining flow through a narrow annular orifice is almost certainly due to chokeage by fine particles in suspension. The mechanism is that bridging appears to occur. Exactly the same experience will be observed with let-down valves, i.e., control cannot be maintained unless the valve diameter is sufficiently small to ensure that they do not have to be operated in the cracked position.

An analogous case occurs with small water flows; where the small orifice, particularly when formed by rubber clips, builds up with algae, and the water flow progressively falls off in the course of a few hours.

Yours faithfully,

W. F. CAREY.

Dear Sir,

I read with interest the letter in the current issue of the Club Bulletin on the possible effect of "stiction" in valve seatings.

It seems to me that the phenomena might be explained in terms of surface roughness.

In the case of the seizure of valves on standing, the normal explanation in terms of the extrusion of the boundary grease film is unconvincing, but if we bear in mind the fact that a metal surface is only apparently smooth, this basic idea can be given some meaning. With regard to the magnitude of surface roughness, one can quote from Bikerman's book, "Surface Chemistry for Industrial Research" (p. 169).

Specimen.				Average Roughness Height (cm.)
Lapped micrometer anvil	...	...	...	1.5×10^{-6} .
Lapped steel	...	...	...	8×10^{-6} .
Ground metal surfaces in autobuses and lorries	...	...	...	$10 - 130 \times 10^{-6}$.

If two surfaces are held together under minimum pressure, the mean distance of separation will be of the order of twice the average roughness height. These dimensions are considerably greater than those of the hydrocarbon molecule. In the case of the closure of a screw valve the pressure will be greater than the minimum and it is very probable that in the region of surface asperities the metals will be in direct contact and owing to the high local pressures developed in these regions it is possible that incipient welding will take place, in addition to the local extrusion of lubricant. These effects would take some time to develop and would call for a relatively large force on opening the valve.

There is another factor which will operate simultaneously. It is well established that if two lubricated surfaces approach within a distance of the order of 10^{-5} cm., there is an apparent rise in the viscosity of the intervening fluid film. This is ascribed by Bikerman to the fact that the liquid can only move in the irregular channels formed by the surface roughnesses and that mechanical interlocking may take place between suitably disposed asperities (loc. cit. pp. 246 et seq., particularly pp. 249-50). This explanation can account for at least part of the initial time factor necessary to the appearance of the effect and also for a significant part of the effect itself.

The second phenomenon mentioned in the letter seems to arise from the same fundamental cause, for it disappears if the dimension of the channel normal to the surface is increased and the flow rate compensated by an increase in dimension parallel to the surface. I could put forward a tentative explanation for the discontinuity of flow, but I would rather delay it for a while, as I am interested in its objective establishment in another context. If the idea is valid I will write to you later.

I remain, Yours sincerely,

J. E. ADAMSON.

RHEOLOGY ABSTRACTS

NOTE.—The initials following the Abstracts are those of the abstracting member, except for the following abbreviations for abstracts produced from other journals by permission :—

B.C.R.A.	British Ceramics Research Association.
I.D.I.B.	Industrial Diamond Information Bureau.
NICKEL BULL.	Nickel Bulletin.
P.A.T.R.A.	Printing and Allied Trades Research Association.
SCI. ABSTR.	Science Abstracts.
B.S.A.	Building Science Abstracts.

933. **Development and Application of Electric Strain Gauges for Static and Dynamic Stress Measurement.**

A. R. ANDERSON. *Schweiz. Arch. angew. Wiss. Tech.*, **13**, 321, 1947.

Strain gauge elements consist of looped wire glued on paper which is bonded to the specimen by synthetic resin. Steel alloy wire is used for dynamic loads and temp.-insensitive Ni-Cu alloy wire for static loading. Several bridge circuits for static measurements, and instruments for determining Poisson's ratio, and strain gauge measurements of welded plate stresses are described. For dynamic stresses, a 60 c/s "Brush" recording oscillograph and a multi-channel oscillograph in conjunction with l.f. oscillator and camera are used. The paper gives results of stress measurements on ships during launching, naval gun structures, Diesel engine crankcases, rifles during firing, and Izod specimen during impact tests. For higher temperatures paper-mounted gauges are replaced by bakelized elements. SCI. ABSTR.

934. **A New Device for Maintaining Constant Stress in a Rod Undergoing Plastic Extension.**

E. N. DA C. ANDRADE. *Proc. Phys. Soc.*, **60**, 304, 1948.

A simple mechanical device is described by which constant stress may be maintained during the plastic extension of a wire. The mid-point of the wire maintains its position during extension, so that it may be observed by a fixed microscope.

AUTHOR'S ABSTR.

935. **Reliability of "Workability Index" of Fire-Clay Plastic Refractories.**

ANON. *Industr. Heat.*, **14**, 1336, 1947.

Workability index has been defined as the measure of the ability of plastic refractories to flow without cracking when rammed, and not deform during subsequent drying. The present A.S.T.M. Test uses a sand rammer consisting of a cylindrical mould of 2 in. inside diameter, and 4½ in. long, open at both ends, with a plunger, and a 14-lb. weight which slides on the shaft. Test specimens are formed by putting 300 g. of plastic material in the mould and subjecting it to 10 impacts of the weight at each end. The percentage deformation or workability index is calculated on the original length. Acceptable limits are 15-35%, and the specimen must not crumble under 3 impacts. Different mountings of the rammer, lubrication or lack of lubrication of the mould, the method of putting the material in the mould, and variability of water content in different parts of the specimen are factors found to affect results appreciably. In some cases, 20 impacts in forming did not give a sample of maximum bulk density. Steel discs used in the ends of the cylinder while forming the test specimens are recommended. B.C.R.A.

936. **Rapid Measurement of the Viscosity of Slags.**

ANON. *Verre Silicates Industr.*, **22**, 112, 1947.

An apparatus is described which is based on the universal viscometer of Höppler. The gradient and size of the tube are chosen so that the flow has a laminated characteristic, and in these conditions the coefficient of viscosity is directly proportional with the speed of fall. The equation being

$$\pi = K(S_b - S_s)t_x$$

where π = dynamic viscosity of the slip in centipoises.

t_x = duration of fall of the ball in the dry slip between two reference points,

S_b = specific gravity of ball in g/c.c.,

S_s = specific gravity of slip in g/c.c.,

K = coefficient characteristic of the apparatus taking into account the diameter of the ball, gradient of the tube, and temperature.

B.C.R.A.

937. **Measurement of the Viscosity of Glass at Low Temperature.**

ANON. *Verre Silicates Industr.*, **23**, 154, 1947.

The viscosity of glass during the interval of annealing can be determined by measuring the deformation of a test-piece under the action of a constant external force. By means of certain conventions, the formulae of elasticity of solid bodies can be applied to viscous fluids, and it is possible to calculate viscosity from simple relations. A study of deformation/time curves shows that there are three types of deformation—instantaneous, retarded, and viscous. The formulae for calculating viscosity cannot be applied until the viscous discharge has been definitely established.

B.C.R.A.

938. **Some Rheological Properties of Carbon Black Suspensions.**

J. E. ARNOLD. *Paint Ind. Mag.*, **62**, 409; *Official Digest, Fed. Paint and Varnish Production Clubs*, No. 274, 619, 1947.

A discussion of the thixotropic properties of carbon black in non-polar paraffin containing very small additions of a third component. An instrument for the measurement of thixotropy in absolute units is described and illustrated. Details of the 3-component system are given. The effect of various added compounds and the effects of order of addition of the third component and of its concentration are noted.

P.A.T.R.A.

939. **Studies in Polymerization. II. A Method for Investigating the relation between the Molecular Weights and Intrinsic Viscosities of Polymers, and its Application to Polystyrene.**

C. H. BAMFORD and M. J. S. DEWAR. *Proc. Roy. Soc. A*, **192**, 329, 1948.

A simple method is described. Unbranched polystyrene is found to obey Houwink's law with an exponent of 0.65. Equations are given for calculating the number average degree of polymerization and molecular weight distribution in unfractionated polymers. It is pointed out that a method is now available for the preparation of polymers with known molecular weights and distribution. The absolute value of the velocity constant for the transfer reaction between styrene and carbon tetrachloride at 60°C. is calculated.

SCL ABSTR.

940. **Hardness Tests. Influence of Dimensional Surface Conditions.**

B. BASTIEN and A. POPOFF. *Technique Moderne*, **39**, 381, 1947.

Discussion of three hardness testing methods, Herbert pendulum, Vickers diamond, diamond indenter (Durometer E.P.). Measurements independent of dimensional surface conditions. (1) Herbert pendulum, mass 4 kg. 1 mm. ball, 10

oscillations of small amplitude. 25 micron depth of impression on extra soft annealed steel, only 1 to 3% dispersion dependent on surface conditions. (2) Vickers, 4 kg., 40 microns impression on soft steel as above, 13 microns impression on soft steel as above, 13 micron on hardened high-speed steel, dispersion great for hard steel. The Vickers diamond point used was not perfect. Micro-geometrical tracing of surface through Vickers impression suggested where profilograph not available. (3) Durometer E.P. dependent on surface conditions as initial load 200 g. not sufficient to exclude error through surface roughness. Herbert pendulum method may give hardness values according to surface whether applied at right angles or parallel to serrations. I.D.I.B.

941. **Kolmogoroff's Theory of Locally Isotropic Turbulence.**

G. K. BATCHELOR. *Proc. Camb. Phil. Soc.*, **43**, 533, 1947.

Kolmogoroff's theory of turbulent motion [*C.R. Acad. Sci. U.R.S.S.*, **30**, 301, 1941; **32**, 16, 1941.] is briefly outlined. The basic notion of the theory is that, at high Reynolds number, all kinds of turbulent motion of arbitrary mean-flow characteristics show a similar structure if attention is confined to the smallest eddies. The motion due to these eddies is isotropic and statistically steady. Within this range of eddies two limiting processes are recognized. The influence of viscosity on the larger eddies of the range is negligible if the Reynolds number is large enough. The quantity of energy continually passed on to smaller eddies from larger eddies is the local mean energy-dissipation due to turbulence. The smaller eddies dissipate, owing to viscosity, a considerable part of the energy they receive, and motion of the very smallest eddies is entirely laminar. Motion due to eddies $<$ a certain limiting size in an arbitrary field of turbulence is thus determined uniquely by viscosity and the local mean energy-dissipation per unit mass of fluid. The mathematical method of describing motion due to eddies of a particular size is to construct correlations between differences of parallel velocity-components at two points at an appropriate distance apart. Scalar functions occurring in the expressions for the correlations are determined by dimensional analysis. Consequences of the theory in turbulent flow possessing ordinary isotropy are analysed and predictions made. The prediction that the dimensionless ratios of moments of the probability distribution of the rate of extension of fluid in any direction are universal constants, has been confirmed by recent experiments by Batchelor and Townsend so far as second and third moments are concerned. Other predicted relations have the correct form.

SCI. ABSTR. (see Abstr. 525).

942. **A Study of Lubricating Wax Coatings by Electron Diffraction.**

C. R. BERRY. *Phys. Rev.* **73**, 1117, 1948.

The claim is made that "certain thin coatings of carnauba wax have different lubricating qualities, although no other physical difference was apparent". Two coatings of different lubricating quality were examined by electron diffraction. The good lubricant gave a diffraction pattern which showed considerably more preferred orientation than that of the poor lubricant. Both buffing and heat treatment of the original specimens produced poorer preferred orientation than before and corresponding poorer lubricants.

An interpretation of the diffraction patterns in terms of the work of Karle and Brockway (*J. Chem. Phys.*, **15**, 213, 1947) was attempted, and a rough comparison of the intensities of the diffraction maxima when the electron beam was at 0, 45 and 90 degrees to the direction of coating of the wax layer indicated that the plane of the carbon atoms had a preferred orientation at 90 degrees to the direction of coating.

The calculated pattern for a long carbon chain does not account for two groups of intensity maxima which occur in the pattern of the more highly oriented specimen.

R.S.

943. Rate of Wear in the Region of the Validity of Amonton's Law.

H. J. BEZER and R. SCHNURMANN. *Nature*, **161**, 728, 1948.

Using a four-ball apparatus of the Boerlage type, $\frac{3}{8}$ -in. steel balls, with "extreme pressure" $> 15,000$ kg./cm.² lubricants which reduced the thermo-electromotive forces generated at the area of contact also reduced the final wear diameter produced by a revolving steel ball loaded against a metal plate. The work done in abraiding matter from the clamped steel balls was a small proportion (about 10^{-3}) of the total frictional work, the main portion apparently being used for shearing the boundary layer. E.W.J.M.

944. Third-order Elastic Coefficients of Crystals.

S. BHAGAVANTAM and D. SURYANARAYANA. *Nature, Lond.*, **160**, 750, 1947.

The authors have extended their methods, based on group theory, of calculating the numbers of higher-order coefficients, needed for the description of elastic behaviour of crystals of different classes, to the case of finite strain. The total number of coefficients required for each class is listed. In the case of cubic crystals, they agree with those of Birch except that 6 is given instead of 8 in the T_4 class; Birch's error is explained. SCI. ABSTR.

945. Calculation of Diffuser Efficiency for Two-Dimensional Flow.

R. C. BINDER. *Trans. A.S.M.E.*, p. A213, 1948.

A method is presented for calculating the efficiency of a diffuser for two-dimensional, steady, incompressible flow without separation. The method involves a combination of organized boundary-layer data and frictionless potential-flow relations. The potential velocity and pressure are found after the boundary-layer growth is determined by a trial-and-check calculation. AUTHOR'S ABSTR.

946. On the Inhomogeneity of Plastic Deformation in the Crystals of an Aggregate.

W. BOAS and M. E. HARGREAVES. *Proc. Roy. Soc. A.*, **193**, 89, 1948.

The variation of plastic deformation in Al specimens consisting of large crystals has been determined by measuring elongation and hardness at various points after tensile deformation. The deformation varied from grain to grain, and also within each grain the deformation near the boundary was $>$ or $<$ at the centre according to whether the neighbour was more or less deformed, i.e., there is not necessarily inhibition of slip near grain boundaries. These results were supported by metallographic and X-ray observations. Their importance with respect to the calculation of the stress-strain curve of aggregates from those of single crystals is discussed. It is suggested that a mechanism other than slip operates near the grain boundaries during deformation, and even within the crystals during large extensions. SCI. ABSTR.

947. Electro-Acoustic Method for Experimental Research on Elasticity.

P. G. BORDONI. *Nuovo Cim.*, **4**, 177, 1947.

Longitudinal waves are excited in a metal rod, and also detected, by a capacity electrode close to one end of the rod. The received signal is frequency modulated, and extraneous noise is filtered out so effectively that, in addition to larger vibrations satisfactory for determinations of elastic constants, vibrations as low as $0.1\text{\AA}$ can be detected. These can no longer be interpreted in the usual macroscopic way, but must be regarded as Brownian motion components. Some examples of the applications are given, e.g., the effect of small cavities on sound velocity of an Al bar. The damping due to air $\gg$ the internal damping, and this, together with the effect of mechanical supports, is discussed from a theoretical standpoint. SCI. ABSTR.

948. **Some Observations of Waves and other Fluctuations in a Tidal Current.**

K. F. BOWDEN. *Proc. Roy. Soc. A.*, **192**, 403, 1948.

Observations have been made of fluctuations in the speed of a tidal current with periods of about 2 sec. upwards. At the same time pressure-gauge records were obtained, showing oscillations due to the wave motion. Both current and pressure measurements were made at various depths between the surface and the bottom. From the pressure records, the rate of attenuation of wave pressures with depth has been shown to follow the theoretical equation, within the limits set by the experimental conditions. The current variations have been classified into short-period and long-period fluctuations. The short-period fluctuations correspond approximately in period to the waves, and their amplitudes are of the same order of magnitude as the calculated wave-particle velocities. The correspondence is not complete, however, and, while it appears probable that the current fluctuations are largely due to the particle velocities of the waves, the possibility of other fluctuations of similar or shorter periods being present is not excluded. The periods of the long-period fluctuations vary from 30 sec. to several minutes, and their amplitude, which increases with the mean current and with depth, sometimes attains 0.4 of the mean current.

SCI. ABSTR.

949. **Oil Flow and Temperature Relations in Lightly Loaded Journal Bearings.**

J. BOYD and B. P. ROBERTSON. *Trans. A.S.M.E.*, p. 257, April, 1948.

Two bearings, A. and B., were studied experimentally to evaluate the rates of flow of oil in them and their temperature characteristics during running under light loads and high speeds. Bearing type A. was a 360° plain bearing with a circumferential groove at mid-length whilst type B. was a similar bearing with a single oil-supply hole on top at mid-length.

The equations formulated by Muskat and Morgan and by others were used to check the theory of flow in these bearings against the experimental data. The chief point of these equations is that the eccentricities attained under low loads and high speeds are assumed to be negligible. After presenting the equations and describing the experimental procedure and results, the authors conclude that at high speeds there is agreement between theory and fact. At low speeds eccentricities are not negligible and, consequently, there is greater divergence between predicted and actual results than at high speeds. When corrections for the eccentricity effect were introduced, the calculated results at 0 r.p.m. agreed with experimental observations. At high speeds it is necessary to allow for the effects of centrifugal forces in the oil in the design of type A. bearings.

It was found that heat losses through the housing were negligible compared with the heat carried away by the oil.

Type B. bearing allows only 0.28 of the flow in type A. under similar conditions. Consequently, type B. will run at higher temperatures than type A. A.H.N.

950. **Calculation of the Error due to Leakage in the Hydraulic Ram Method of Pressure-Calibration.**

J. W. BREMNER. *Phil. Mag.*, **38**, 564, 1947.

The pressure to maintain the leakage in the annular gap between the ram and the cylinder is calculated on the assumptions that the pressure over the base of the ram is of the same value at each point of the base, that the ram and cylinder are truly cylindrical, that the ram moves coaxially with the cylinder, that Poiseuille flow takes

place in the annular gap. The boundary conditions are that there shall be no slipping of the liquid with respect to the walls of the ram and the cylinder. The result of the calculation is :

$$p = \frac{4\eta}{(R^2 + \rho^2) \log R/\rho - (R^2 - \rho^2)} l \frac{dl}{dt}$$

where l = penetration of ram into cylinder, R = radius of cylinder, ρ = radius of ram, η = viscosity of liquid. With an annular gap of half of one-thousandth of an inch and a radius of 0.18 inch, the pressure calibration will be in error by about 0.3% owing to leakage. R.S.

951. Physical Properties of Electrodeposited Chromium.

A. BRENNER, P. BURKHEAD and C. JENNINGS. *J. Res. Nat. Bur. Stand., Wash.*, **40**, 31, 1948.

The following properties of Cr, deposited under a wide variety of plating conditions, have been measured ; density, hardness, tensile strength, Young's modulus of elasticity, ductility, electrical resistivity, and stress in the deposit. The O and H content were determined. The effect of heat treatments up to 1,200° C. on certain of these properties has been determined and some work has been done on the properties of Cr-Fe alloys deposited from modified chromic acid solutions. A relation between the H and O content of the deposits has been shown to exist, and the effect of the O content on the physical properties has been studied. SCI. ABSTR.

952. A Calculation of the Viscosity and the Sedimentation Velocity for Solutions of Large Chain-Molecules Taking into Account the Hampered Flow of the Solvent through each Chain Molecule.

H. C. BRINKMAN. *Proc. K. Ned. Akad. Wet.*, **50**, 618, 821, 1947.

Using a single model and assuming that in solutions of long-chain polymers the flow of solvent through the molecular clusters is hampered as if the cluster was a porous sphere, calculations are made of both viscosity and sedimentation velocity. The amended calculations show reasonable agreement with published data on viscosity but the agreement is not so good with known sedimentation constants. SCI. ABSTR.

953. A Calculation of the Viscous Force exerted by a Flowing Fluid on a Dense Swarm of Particles.

H. C. BRINKMAN. *Appl. Sci. Res.*, **A1**, 27, 1947.

The model underlying these calculations is that of a spherical particle embedded in a porous mass. The flow through this porous mass is described by Darcy's equation, modified to obtain consistent boundary conditions. A relation between permeability and particle size and density is obtained. The results are compared with an experimental relation due to Carman. SCI. ABSTR.

954. The Brittle Fracture of Pre-Cracked Solids.

R. L. BROWN. *Research*, **1**, 93, 1947.

A theoretical consideration of the fracture of pre-cracked solids is shown to suggest a relationship between the shatter strength of equal-sized lumps and the sieve analysis of the consignment from which the lumps are taken. Experimental evidence obtained with a friable coking coal is given in support of the theory. B.C.R.A.

955. **The Internal Flow of Granular Masses.**

R. L. BROWN and P. G. W. HAWKSLEY. *Fuel Sci. Pract.*, **26**, 159, 1947.

The paper consists of a report on exploratory investigations of the phenomena of packing and flow of particles. The first part of the investigation consists of experiments carried out with a single layer of ball bearing—resting on an inclined glass plate. Movable walls perpendicular to the glass plate hold the packing in position, and are sheared to deform the packing as required. The resulting dilatations of the packing and non-uniformities of void distribution within it are examined at length photographically. Although the observations refer to packings of equal spheres, the universality of the principle of dilatancy suggests that they would also apply to packings of mixed particles. In the second part of the investigation fine sand contained within two vertical glass plates was allowed to pass downwards through the plug and the formation of the flowing sand was observed by stopping the flow at various stages. It is shown that the flow is irregular and asymmetrical, and that the particles tend to move in groups. B.C.R.A. (see Abstr. 315).

956. **On the Influence of the Concentration of a Suspension upon the Sedimentation Velocity (in Particular for a Suspension of Spherical Particles.)**

J. M. BURGERS. *Proc. Ned. Akad. v. Wetenschappen*, **44**, Nos. 9 and 10, 1941; **45**, Nos. 1 and 2, 1942.

The papers describe an attempt to find the magnitude of the effect of the mutual influence of the particles (spheres) of a suspension upon their velocity of sedimentation. The author first considers the view that not the density of the suspending liquid but the mean density of the suspension must be used in calculations; next the presence of the particles brings about an increase of the effective viscosity of the liquid for every particle taking part in the translational and rotational movements of the elements of volume surrounding it and so experiences a system of forces (represented by a system of doublets) which will react upon the liquid. The effective coefficient of viscosity of the suspension is given by $\eta_{eff} = \eta(I + nk)$, where k is a coefficient and n the number of particles per unit of volume. The sed. vol. of any particle is the resultant of the direct influence of the gravitational force, calc. with the value η_{eff} and the velocity imparted to the liquid in consequence of the fields of flow produced by all the other sedimenting particles. The influence exerted upon a neighbouring particle dragged along the same direction of movement is of the order a/r , a being the radius of the particles and r the distance between them. In an assembly of a large number of particles the contributions to be derived from more and more distant groups do not form a convergent series and depend on the extent and shape of the assembly, as well as upon the conditions imposed by the properties of the surrounding field. In a vessel a return flow somewhere occurs and there will be a negative effect between particles at distances comparable with the dimensions of the vessel and the two effects may nearly balance each other.

Burgers draws a "picture" of the field of flow; the suspension consists of a liquid of density, ρ , acted upon by a force ρg per unit vol. and in which are embedded n particles per unit volume every one of which is acted upon by a force $W = s \rho_p g$ (s being the volume and ρ_p density of particles.) All forces acting in the same direction can be analysed into a continuous field of force with intensity, $\rho g + nF$ per unit volume acting through the whole space and a set of "equilibrium systems" each system having its centre at the particle centre.

E.W.J.M. (see Abstr. 436, 437).

957. **The Creep Characteristics of Copper and some Copper Alloys at 300°, 400° and 500° F.**

H. F. BURGHOFF and A. I. BLANK. *Proc. A.S.T.M.*, **47**, 1947.

The paper is the third in a series of reports on the creep properties of copper and copper alloys (for Parts 1 and 2 see *Proc. A.S.T.M.*, **42**, 668, 1942; *Trans. Amer. Inst. Min. Met. Eng.*, **161**, 420, 1945).

Data presented relate to the following materials, tested in several cases in more than one condition:—electrolytic, oxygen-free, deoxidized and arsenical coppers; Admiralty metal; aluminium brass; Naval brass; 3% silicon bronze; phosphor bronze; copper-nickel-phosphorus alloy (copper 98.57, nickel 1.15, phosphorus 0.23%), and a free-machining copper-nickel-phosphorus-tellurium alloy (copper 98.09, nickel 1.11, phosphorus 0.28, tellurium 0.51%). All the materials were processed and tested in the form of straight lengths of $\frac{1}{8}$ -in. diameter wire.

The four types of copper which were tested conform to the following order of decreasing creep-strength, in both annealed and hard-drawn tempers; arsenical copper, deoxidized copper, oxygen-free copper, and electrolytic copper. The superiority of the arsenical copper over the other coppers is pronounced: difference between oxygen-free and electrolytic coppers is very slight.

The creep-strengths of Admiralty and aluminium brass in the annealed condition vary with grain-size. Significant differences were observed in the creep behaviour of these two alloys in hard-drawn tempers. The tests indicate that the presence of tin and aluminium in these special brasses contributes little to creep-strength for the annealed condition.

The two age-hardenable alloys, containing nickel and phosphorus (with or without tellurium), showed outstandingly good creep-resistance. In the condition as age-hardened and not subsequently cold-drawn they are susceptible to embrittlement under extreme conditions and temperature, but severe cold-working after age-hardening produced a more stable condition. NICKEL BULL.

958. **A New Method of Measuring Elastic Constants Applicable to Glass.**
R. CABARAT. *Verres et Réfract.*, **1**, 26, 1947.

Measurements of the elastic constants of solids, and of glass in particular, are of considerable interest from the point of view of practical application as well as of the theory of the solid state. The author shows that, by the use of an improved sonic instrument, much greater precision can be achieved than was possible with the methods formerly used for the determination of Young's modulus. Variations of this modulus as a function of temperature can be investigated, and the instrument can be adapted to the measurement of moduli of torsion, and of internal friction.

B.C.R.A.

959. **Generalization of the Formulae of Helmholtz and Cauchy for a Viscous Incompressible Fluid.**

I. CARSTOIU. *C.R. Acad. Sci., Paris*, **223**, 1095, 1946.

The equations are extended to cover the case where vortices arise. They show how Lagrange's theorem ceases to be valid for the fluid considered. SCI. ABSTR.

960. **Electro-Osmosis.**

L. CASAGRANDE. *Proc. 2nd Int. Conf. Soil Mech., Rotterdam*, **1**, 218, 1948.

The electro-osmotic flow Q , across an area of soil A , can be written in the form

$$Q = k_e i_e A$$

where k_e is the "osmotic permeability" and i_e the potential gradient. For a representative number of soils, varying from fine sand, through clays and silts to bentonite,

the value of k_0 is found to be approximately a constant, and equal to 5×10^{-5} cm. per sec. per volt per cm. On the other hand, the amount of current passing per unit area, for a given potential gradient increases with decreasing grain size.

The hydrostatic pressures developed at the cathode were measured and found to agree well with the theoretical value derived from the Helmholtz theory in the case of single grain structures (sand, silt, kaolin). For clays the measured values were appreciably lower than theory would indicate, and this is to be explained by the movement of water through the fissures which are developed in these colloidal materials and which are observed to be filled with free water.

Brief reference is made to the structural features resulting from electro-osmosis in clays, which have previously been described (*Nature* **160**, 470, 1947). A.W.S.

961. Movement of a Viscous Fluid between Concentric Spheres.

F. CHARRON. *C.R. Acad. Sci., Paris*, **223**, 1098, 1946.

An experimental study is made of the motion of the fluid when the inner sphere (of steel) rotates with respect to the outer sphere (of glass). The torque is measured and the movement of the stream lines is followed by injecting a coloured thread of liquid and observing with a microscope. SCI. ABSTR. (see Abstr. 850).

962. Stress Corrosion.

J. C. CHASTON. *Nature*, **161**, 891, 1948.

An explanation of stress corrosion ("season-cracking") in brass and similar alloys is offered on the basis that selective chemical attack occurs at the grain boundaries, localized by the formation of a protective film of corrosion product over the face of the alloy crystal. The effect of stress is considered to be simply that of widening the cracks first formed and thereby accelerating attack. Results of an experiment were in favour of this explanation. E.W.J.M.

963. Flow of a Compressible Fluid about a Cylinder.

T. M. CHERRY. *Proc. Roy. Soc. A.*, **192** 45, 1947.

In contrast to the approximate solutions found by "velocity-correction" methods, a family of *exact* solutions is here found, by the hodograph method. The theory is restricted to the case of zero circulation and the speed at large distances from the cylinder is subsonic, while the speed near the cylinder is not so restricted. The family of solutions involves an ∞ set of constants, which determine the shape of the cylinder. The velocity components are taken as independent variables, and the field equation is linear. The solution is based on a theorem whereby a hypergeometric function with large parameters is expressed as a convergent series whose leading term represents the function asymptotically. The primary solution obtained represents flow round a cylinder which is approximately circular when the velocity at ∞ (q_1) is small, but which becomes flattened as q_1 increases. Discussing the recent work of Tsien and Kuo on this subject, the author shows that their theory of the analytical continuation of solutions is essentially defective. An improved assumption used by Tsien and Kuo is shown, in the case of their chief example, to be false.

SCI. ABSTR.

964. On the Stresses in a Plate containing Two Circular Holes.

CHIH-BING LING. *J. Appl. Phys.*, **19**, 77, 1948.

A theoretical solution is given for the case of two holes of equal size. Detailed calculations for three fundamental types of stressing are given, as well as figures for the maximum stress. L.R.G.T.

965. **Stresses in a Plate containing an Overlapped Circular Hole.**

CHIH-BING LING. *J. Appl. Phys.*, **19**, 405, 1948.

A similar treatment to the above (964) for the case when the two circular holes overlap. L.R.G.T.

966. **Laboratory Studies relating to the Clay Fraction of Cohesive Soils.**

K. E. CLARE. *2nd Int. Conf. Soil Mech., Rotterdam*, **1**, 151, 1948.

The relations between the liquid limit and plasticity index of Atterberg for a wide range of British soils are given, together with the ignition loss at 800°C. expressed as a percentage of the clay fraction. The effect of sodium oxalate concentration in dispersing a kaolinite and montmorillonite clay is studied, and a micro-sedimentation apparatus for determining particle size below 2 microns is described. A.S.K.

967. **The Measurement of the Damping Capacity of Metals in Torsional Vibration.**

G. A. COTTELL, K. M. ENTWISTLE and F. C. THOMPSON. *J. Inst. Met.*, **74**, 373, 1948.
The estimation of specific damping capacity from measurements of experimental decay curves.

G. L. J. BAILEY. *Ibid.*, 415, 1948.

The cause of the discrepancy between the results of "mechanical" and "physical" methods of measuring damping capacity in torsional vibration has been investigated. It was found that in the case of a machine of the Föppl-Pertz type, as hitherto constructed, the energy loss in the machine itself may, when testing a material of low damping capacity such as Duralumin, amount to ~ 500 or more $\times$ the intrinsic energy dissipation of the specimen. All the major sources of loss have been isolated, and complete re-design of an existing machine has reduced the measured damping to the order of $2 \times$ the lowest values measured by the physical method. The use of a solid of revolution in place of the usual rectangular bar as the oscillating inertia was found essential. The air-friction energy loss over the surface of the oscillating wheel was measured to determine the air-loss correction. The damping capacity of Duralumin agreed very well with the lowest determinations by physical methods. This investigation confirms that the physical and mechanical methods are in fact measuring the same property, and shows that, at least for Al alloys, results of the same order can be obtained by the two methods, provided that the apparatus is designed correctly. SCI. ABSTR.

968. **Annealing of Glass.**

S. M. COX. *Nature*, **161**, 401, 1948.

An equation for stress relaxation is derived assuming that the change in state of glass associated with temperatures about and above the annealing range is due to the development of "holes" (or two positioned sites for some of the ions) with increasing temperature. E.W.J.M.

969. **Bending Stresses in Wire Ropes.**

E. CZITARY. *Ost. Ingen. Arch.*, **1**, 342, 1947.

A mathematical investigation based on kinematic considerations shows that Reuleaux's expression $E\delta/2r$, for the bending stress of the wires in ropes is correct if the radius of curvature r , $\gg$ rope diameter. (E = Young's modulus, δ = thickness of wire). The results of the investigations are in accordance with test results which show that (1) the wires within a half-winding of a spiral rope are shifted

from the concave inner to the convex outer side, the largest shift occurring in the middle section, (2) no longitudinal forces appear in the wires, (3) the rope cross-section remains essentially plane. Torsional forces may be neglected. Conclusions are drawn on the behaviour of stranded ropes consisting of inter-twined spiral ropes. For relatively small twisting angles of the spiral ropes and the stranded ropes the change of curvature is $\sim 1/r_0$, independent of the fact whether the twist of the stranded rope is in the same or the opposite direction of that of the spiral rope.

SCI. ABSTR.

970. **Investigations in the Domain of Rubber Vulcanization. VI. Changes in the Moduli in Two-directional Extension during the Vulcanization of Natural and Butadiene-Styrol Rubbers.**

B. DOGADKIN, G. BARTENEV and N. NOVIKOVA. *Kolloidnyi Zhurnal*, **10**, (2), 94, 1948

971. **Torsional-Fatigue Testing of Marine Shafting.**

S. F. DOREY. *Engineering*, March 19th, p. 286, 1948.

Full scale torsional fatigue tests, carried out on a new type of shaft, consisting of thick solid-drawn steel tubes, in place of forged shafts, is described.

A novel torsional vibration sampler, as designed originally by Dr. G. H. Forsyth, was used as a torque exciter in the construction of a large torsional-fatigue testing machine. Details of the latter are given.

Results show that unless very special care is taken in welding, couplings welded to shafts may have a comparatively low fatigue strength under alternating torsional stresses, probably due to structural heterogeneity in the weld area. M.W.T.

972. **The Visco-Elastic Behaviour of a Highly Elasticized Nitrocellulose in Compression under Constant Load.**

G. J. DOYLE and R. M. BADGER. *J. Appl. Phys.*, **19**, 373, 1948.

The behaviour of a highly plasticized nitrocellulose in compression under constant load has been investigated over a rather wide range of load and temperature. The load dependence appears to require the assumption of non-Newtonian viscosity. Though the observations are not quantitatively accounted for by the Tobolsky-Eyring model, the load and temperature dependence of the rate of compression appear to have some relation to the predictions of these authors. AUTHORS' ABSTR.

973. **Experiments on the Effect of Low Temperature on some Plastic Properties of Metals.**

M. J. DRUYVESTEYN. *Appl. Sci. Res.*, **A1**, 66, 1947.

The yield value, breaking strength, elongation and hardness of a number of pure polycrystalline metals were measured at room temperature and at -183°C . The yield value is always higher at -183°C . than at 20° , the difference being relatively small ($< 75\%$) for the cubic face-centred and a number of hexagonal metals (e.g., Mg.). This difference is large for the body-centred metals and for Zn, Cd and Sn. The former metals have a larger elongation at lower temperature, the latter however become more or less brittle at low temperature. The breaking strength and the hardness increase generally with decreasing temperature. SCI. ABSTR.

974. **The Thermodynamics of Irreversible Processes. IV. The Theory of Elasticity and Anelasticity.**

C. ECKHART. *Phys. Rev.*, **73**, 373, 1948.

A classical theory of anelasticity is outlined, after removing two traditional

false assumptions: the principle of a constant relaxed (or standard) state; and the principle of macro-relaxability, which is replaced by micro-relaxability, analogous to Riemann differential geometry. It is first shown that the variability of the relaxed state makes the density of the substance independent of the strains. Consequently the internal energy can depend on the specific volume as well as on the strains and the entropy. The expression for the rate of increase of entropy is then derived. As usual, this suggests, but does not uniquely determine the form of the dissipative laws. In addition to the usual equations for the viscous stresses, one is led to another set of equations involving parameters that quantitatively describe the anelastic properties of the substance. These results are used to derive the equations for the waves of distortion and dilation in an ideal isotropic anelastic medium. When the two coefficients of viscosity and two coefficients of anelasticity all vanish, these reduce to the usual equations for such waves. In addition to the 4 dissipative coefficients, the isotropic anelastic substance is characterized by 4 elastic moduli, rather than by the 2 that characterize an isotropic elastic substance. Thus, there are 8 parameters whose values can be adjusted to describe the particular substance. When the 4 dissipative parameters do not vanish, the propagation of the waves can be described by 5 relaxation times. The ideal isotropic anelastic substance thus has a relaxation spectrum of about the same complexity as those of actual substances. The kinematic independence of the density and the strains causes a hydrostatic pressure to have different dynamic effects from a uniaxial pressure. This is in accord with experiment—the latter being much more effective in producing anelastic deformation than the former.

SCI. ABSTR.

975. Cathode-Ray Recording Micrometer and Force Gauge.

J. EWLES and C. CURRY. *J. Sci. Instrum.*, **24**, 261, 1947.

A description is given of a device using a cathode-ray oscillograph in conjunction with a moving-coil system to record and measure rapidly varying movements of the order of 3 mm. to an accuracy of 0.0025 mm. By attaching the moving coil to a specially designed force gauge of natural period of about 1/5,000 sec. the device has been applied to record and measure rapidly varying forces and to a preliminary study of rapid shear.

B.C.R.A.

976. On the Decrease of the Kinetic Energy of a Viscous Incompressible Fluid Occupying a Bounded Flat Domain.

J. K. DE FÉRIET. *C.R. Acad. Sci., Paris*, **223**, 1096, 1946.

It is shown that the kinetic energy, $E(t)$, at a given time t , is of the form $E(t) = E_0 e^{-\alpha t}$, and the constant α is evaluated.

SCI. ABSTR.

977. Critical Density of some Dutch Sands.

E. C. W. A. GEUZE. *2nd Int. Conf. Soil Mech., Rotterdam*, **3**, 125, 1948.

Since dense sands exhibit the phenomenon of dilatancy during shear, and loose sands are found to compact, there must be a certain *critical porosity* at which no volume changes took place. This critical porosity was determined on four sands, using a specially adapted triaxial apparatus and a procedure of test in which the normal pressure on the shear plane was kept essentially constant. The results varied from a porosity of 48% for a uniform very fine sand, to about 40% for a graded coarse sand.

Two of the sands investigated had been involved in flow slides on an extensive scale. In both cases the actual porosity of the sand in the field was found to be slightly in excess of the critical porosity as measured in the laboratory.

A.W.S.

978. **The Development of Soil Mechanics in England.**

H. Q. GOLDER. *Verre Silicates Industr.*, **12**, COBEA Suppl., 9, 1947.

Techniques at present employed in Great Britain are almost entirely unknown on the Continent, on account of lack of inter-communication during the war years. By visiting laboratories in different countries the author realized that the problems of soil mechanics in each country, and the methods of their solution, were conditioned by the geology of that country, and a number of examples are quoted. Two methods of measuring shear strength are used in Great Britain; one is a test at constant moisture content, the immediate shear test, and the other, or equilibrium shear test, is carried out on samples which have reached equilibrium under different normal loads or lateral pressures. Most construction problems are solved by the $\phi = 0$ analysis, which assumes that the angle of the internal friction of the clay for suddenly applied loads, or conditions of constant moisture content, is zero. It is concluded that the unconfined compression test and the above-mentioned method of analysis are justified by experience for British conditions. B.C.R.A.

979. **The Angle of Shearing Resistance in Cohesive Soils for Tests at Constant Water Content.**

H. Q. GOLDER and A. W. SKEMPTON. *Proc. 2nd Int. Conf. Soil Mech., Rotterdam*, **1**, 185, 1948.

The angle of shearing resistance ϕ defines the rate of increase in strength of a soil with increasing applied normal pressure on the shear plane. For saturated clays, covering the full range of strength from soft to very stiff, the value of ϕ is found to be zero, for the condition in which the clay is tested without water content change. For silts and partially saturated clays ϕ is always greater than zero and may attain values as high as 35° . With partially saturated clays this result is attributed to compaction (i.e., reduction in air voids) and to micro-consolidation at the points of contact of the aggregated particles of clay; while in silts the gain in strength can be explained in terms of dilatancy. Results on 40 samples are reported.

A.W.S. (see Abstr. 163).

980. **Annealing Temperature and Hardness of Tantalum.**

J. N. GREENWOOD and R. H. MYERS. *Nature, Lond.*, **160**, 675, 1947.

Tantalum is hard and brittle after heating to $1,800^\circ\text{C}$. and cooling quickly, the maximum hardness being dependent on the amount of previous cold working. It becomes soft again on heating to $2,400^\circ\text{C}$. and quickly cooling. SCI. ABSTR.

981. **The Effective Stress Concentration at the End of a Crack in Materials having Atomic Constitution.**

C. GURNEY. *Phil. Mag.*, **39**, 71, 1948.

The crack is assumed to have an elliptic form and the average stress over a small area at the end of the major axis is computed. This involves the ratio of the length to the radius of curvature at the end of the crack, and the case in which this ratio is approx. unity is of special interest, since in practice the smallest radius of curvature and length are of the order of atomic dimensions. The effective stress concentration is then $\sim \frac{1}{2}$ the maximum stress concentration occurring at the line boundary of the hole. SCI. ABSTR.

982. **Fatigue of Mineral Glass under Static and Cyclic Loading.**

C. GURNEY and S. PEARSON. *Proc. Roy. Soc. A.*, **192**, 537, 1948.

Round soda-glass rods were broken in 4-point bending. In one series of experi-

ments, the load was increased at a constant rate until fracture occurred, and in another series, the times to fracture under a range of constant loads were determined. Tests in each series were made under three different test conditions—non-rotating, rotating at 14 and at 10,000 r.p.m. It is concluded from the experiments that glass does not fatigue under cyclic loading appreciably faster than it does under static loading. This was in accord with expectations, if the static fatigue of glass is due to the spread of cracks rather than to deterioration of the inherent strength of flawless material. As fracture of glass under static conditions is not preceded by flow and work hardening as it is for metals, the difference in fatigue behaviour of glass and metals is an indirect indication that the fatigue of metals is associated with flow and work hardening, and this agrees with more direct evidence on the nature of fatigue in metals. SCI. ABSTR.

983. **Delayed Fracture of Glass under Tension, Torsion and Radial Pressure.**

C. GURNEY. *Nature*, **161**, 729, 1948.

A plausible explanation of delayed fracture of glass is that cracks initially present in the unstressed material gradually extend when glass is loaded. As the cracks extend, the stress at the ends of the cracks increases until it becomes equal to the maximum stress which the glass can momentarily withstand; catastrophic fracture then occurs. Delayed fracture experiments in bending, torsion and radial pressure were made on $\frac{1}{4}$ -in. diameter annealed soda glass rods; the points relating stress (lb./sq. in.) and time to fracture were all scattered about the same curve.

E.W.J.M. (see Abstr. 600).

984. **The Swelling of an Orthotropic Circular Tube.**

C. GURNEY and A. HAMMOND. *Trans. A.S.M.E.*, p. A188, 1948.

Many organic sheet materials swell owing to moisture absorption, more in thickness than in directions in the plane of the sheet. An example is laminated synthetic-resin sheet in which thickness swelling is usually between 5 and 10 times the swelling in the plane of the sheet. When a wrapped circular tube is formed of such materials and caused to swell until equilibrium is reached, a state of stress results. If the tube were stress-free, the radial strain would equal the swelling strain of the sheet across the thickness, and the circumferential strain would equal the swelling strain in the plane of the sheet. Geometrical considerations compel the radial and circumferential strains to be related and hence a state of stress is set up. The calculation of the stresses and displacement in a swollen ring is the subject of this paper. The problem is solved in a general form in which swelling strain, Young's modulus and Poisson's ratio have different values in the radial and tangential directions. Three boundary conditions are treated: namely, stress-free peripheries, constant internal diameter, and constant external diameter. Hooke's law and zero stress coefficient of swelling are assumed throughout. The solution has application to wrapped fabric plastic bushings and bearings. AUTHORS' ABSTR.

985. **Time Effect in Connection with Consolidation Tests.**

R. HAEFELI and W. SCHAAD. *2nd Int. Conf. on Soil Mech., Rotterdam*, **3**, 23, 1948.

Consolidation tests on a kaolinitic clay, in which the samples were left under constant pressure for three years, confirm Buisman's hypothesis that the compression after an initial period of consolidation due to the dissipation of hydrodynamic excess pressures in the pore water, continues at a rate directly proportional to the logarithm of time. This law cannot hold good for extremely large time intervals, but no deviation was observed during the three year test. A.W.S.

986. **Non-linear Viscous Elasticity and the Eyring Shear Model.**

G. HALSEY. *J. Appl. Phys.*, **18**, 1072, 1947.

Methods of analysing the stress-strain-time relations for textiles fibres are reviewed. While approximate agreement with experiment is frequently obtained on the basis of a 3-element spring and dashpot model, a more accurate representation is obtained by introducing non-Newtonian dashpots and non-Hookean springs. Alternatively the system may be analysed in terms of a distribution of relaxation times.

The detailed application of these methods to experimental data is discussed.
L.R.G.T.

987. **On the Firmness of Soft Materials.**

R. HARPER. *Amer. J. Psychol.*, **60**, 554, 1947.

A critical extension of the work by Scott Blair and Coppen (*ibid.*, **55**, 215, 1942; **56**, 234, 1943) on comparison of firmness of Newtonian, Hookean and complex bodies judged by squeezing in the hands. The original data are subjected to fuller statistical treatment and a number of corrections are made. An index of fractional differentiation is found which accounts quantitatively for the observed discrepancy, in judgments of mixed pairs of materials, from a "pure strain" criterion for firmness comparison. The significance of non-Newtonian time scales is discussed in relation to psycho-physical processes.

G.W.S.B. (see Abstr. 114).

988. **Note on Forced Flow of a Granular Material.**

P. G. W. HAWKSLEY and J. B. WAGSTAFF. *Fuel Sci. Pract.*, **26**, 153, 1947.

Experiments compare free downward flow and forced upward flow of granular masses from one chamber to another through a tube containing a revolving screw. The results are shown in a series of diagrams. The first experiment, in which grey feed-sand was forced upward into a bed having an initially horizontal free surface, showed that the feed passes through the bed as a solid plug, and only those parts of the bed directly ahead of it suffer any disturbance. When the direction of rotation of the screw was reversed, however, causing the bed to discharge slowly through the tube, the plug was characterized by intense internal flow, and its boundary varied irregularly. In another experiment the material was forced upwards into a bed, the surface of which was inclined. In this case the plug was bent towards the surface.

B.C.R.A.

989. **Electron Microscope and Electron Diffraction Study of Slip in Metal Crystals.**

R. J. HEIDENREICH and W. SHOCKLEY. *J. Appl. Phys.*, **18**, 1029, 1947.

Investigation of pure Al crystals deformed by tension or compression led to the following conclusions: The initial slip occurs in a single (111) plane to a displacement of $\sim 2,000 \text{ \AA}$; this particular plane then resists further motion, and slip begins anew on another (111) plane about $200 \text{ \AA}$ away. The process repeats and results in a laminar slip region which may merge with adjacent ones. The material between visible slip bands is relatively unaffected until the spacing of the bands is reduced to $\sim 5 \mu$ (5% elongation). At higher deformations, rotation of the laminae is indicated.

SCI. ABSTR.

990. **Universal Instrument for Tensile Strength Studies.**

B. IVARRSON and B. STEENBERG. *Svensk Papperstidning*, **51**, 23, 1948.

A universal instrument for tensile studies of paper is described. The instrument is of the chainomatic type with photo-electric control and allows recording of

stress-strain diagrams at a constant rate of elongation or a constant rate of loading and further studies of creep and relaxation at constant elongation. The length of the strip under test can be varied up to 750 mm., and is placed in a conditioned cabinet. Elongations can be read at 0.01 mm. and the stress can in all cases be read to the nearest 7 g. In order to allow automatic recording of both straining and de-straining parts of the diagram the instrument is equipped with contacts which, when touched by a pointer on the chain, reverse the direction of either the elongation or the loading. Generally the instrument is used with a constant rate of elongation of $2.67 \cdot 10^{-5}$ per sec. This low rate is needed in de-straining because the rate of creep of the paper is low. P.A.T.R.A. (see Abstr. 816, 918).

991. Annealing of Glass.

G. O. JONES. *Nature*. **161**, 813, 1948.

The Author comments on the views of S. M. Cox (see Abstr. 968) and points out that under constant stress, glass and other substances obey the following expression :

$$\text{strain} = a + bt + c.f(t),$$

where a , b and c are constants proportional to the stress and dependent upon temperature, composition, etc. The three terms represent respectively the instantaneous reversible elastic strain, the irreversible purely viscous flow at constant rate and the reversible delayed elastic strain. The function $c.f(t)$ has the value 0 at $t = 0$ and c , at $t = \infty$ (Maxwell's equation of visco-elasticity leads to an expression which does not include any delayed elastic effect).

Cox's explanation leads to a single exponential term of the form :

$$[1 - \exp(-t/\tau)]$$

for $f(t)$, whereas for glass the function is probably of the form : $[1 - \exp(-\sqrt{t/\tau})]$.

E.W.J.M. (see Abstr. 329).

992. The Viscosity of Solutions of Primary Alcohols and Fatty Acids in Benzene and in Carbon Tetrachloride.

W. J. JONES, S. T. BOWDEN, W. W. YARNOLD and W. H. JONES. *J. Phys. Coll. Chem.*, **52**, 753, 1948.

An accurate investigation was made of the viscosity of solutions of alcohols and fatty acids in both benzene and carbon tetrachloride over the whole range of concentration from 0 to 100%. In many cases the viscosity-concentration curves exhibited a minimum whose position shifted on preceeding along a homologous series. The observed relationships are not satisfactorily accounted for by any of the theoretical formulae which have been proposed. L.R.G.T.

993. Viscosities of Cis- and Trans-1-2-Dichloroethene in Connection with Eyring's Theory of Viscous Flow.

J. A. A. KETELAAR, L. DE VRIES, P. F. VAN VELDEN and J. S. KOOY. *Rec. Trav. Chim. Pays. Bas.*, **66**, 733, 1947.

Using a modified form of the Ostwald viscosimeter, viscosity-measurements have been carried out over a temperature-range from the melting points up to about 20° C. for the two isomers of 1-2-dichloroethene. Density measurements were made over the same range of temperature. Special care has been taken in purifying the samples used. From the data obtained, values of the free energy, the energy and the entropy of activation for viscous flow have been calculated, using Eyring's theory. It appears that the experimental quantity E_{vis} , defined by :

$$E_{vis} = R d(\ln \eta) / (d(1/T)),$$

has a temperature-independent value of about the same magnitude for both isomers,

whereas Eyring's "energy of activation for viscous flow" is temperature-dependent. It is concluded that both isomers behave as normal unassociated substances, which conclusion is reached as well from consideration of the values of the "rheochor" and from the relation between the surface tension and E_{vis} . SCI. ABSTR.

994. **Proposed Experiments for Further Study of the Mechanism of Plastic Deformation.**

J. S. KOEHLER and F. SEITZ. *Trans. A.S.M.E.*, A217, 1948.

The Authors, after reviewing the general theory of the plastic deformation of solids and the work of C. G. Darwin, W. P. Davey, Andrade, Bragg, A. A. Griffith, and others, in this field, and using schematic diagrams of displacement of crystal imperfections (dislocations of finite length in lattice planes of atoms), after Orowan, G. I. Taylor, Buerger, Burgers and others, construct a "picture" to account for a lower range of Hookean elasticity found with solids (up to 10^7 dynes/cm.²), although quantum mechanical calculation lead to the conclusion that Hooke's law should be valid up to stresses as large as 10^{10} dynes/cm.².

The potential energy of a crystalline block is increased by the introduction of a dislocation, the energy being supplied by the deforming forces. Koehler and Seitz show an electron microscope photograph, after C. S. Barrett, of the mosaic structure in pure annealed copper; dendritic and branching growth from a nucleus favours the development of imperfections. The mosaic structure does not seem to change very much with heat treatment, this being due to the large thermal activation energy (0.5 electron volt per plane) required to break up the structure. According to the picture the density of dislocations in an annealed metal in a plane perpendicular to the slip plane is about 10^9 dislocation lines per sq. cm. In a severely cold worked metal, the work hardening and the amount of stored energy can be understood if one assumes that there are 10^{12} dislocation lines per sq. cm. through a plane perpendicular to the slip plane.

Fie'd stress is affected by surface cracks where dislocation may occur. Dislocation may be prevented from moving freely by insoluble oxides, and it may be supposed that disc-shaped holes are responsible for stress magnification but the ratio of diameter to thickness of the disc must be about 10 to produce the desired stress concentration. Large holes have been found experimentally not to play a part in stress magnification.

The Authors on the basis of their "picture" propose experiments using very pure single crystals of copper and zinc involving the measurement of the internal friction, the electrical resistance and the initial or transient creep rate.

If the measurements of creep and internal friction are done at sufficiently low temperatures and low stresses are used, then the values should drop to zero because the thermal fluctuations are no longer large enough to assist the dislocations over potential barriers. The electrical resistance measurements would furnish information about the "ends" of the dislocations and possibly about the distribution of dislocations in a cold worked specimen. The measurement of the yield stress of very thin wires of pure metal single crystals of known crystallographic orientation and surface condition, after various treatments, such as smoothing the surface by electrolytic polishing, would be valuable and would decide whether stress magnification at cracks is important in plastic deformation and give some idea of the variation in yield stress produced by changing the size and number of the cracks.

The Authors suggest that it would be worth while to subject a pure single crystal of Ag Cl to a small amount of plastic deformation, then expose it to light and finally to examine the Laue X-ray diffraction pattern obtained using the characteristic copper L α radiation on the assumption that silver will be deposited preferentially in regions where the local stresses have increased the lattice parameter.

E.W.J.M. (see Abstr. 786).

995. **An Experimental Study of the Maximum and Minimum Porosities of Sands.**

J. KOLBUSZEWSKI. *2nd Int. Conf. Soil Mech., Rotterdam, 1*, 158, 1948.

This paper is a progress report on research being carried out at Imperial College on the relation between porosity and methods of deposition of sands. It has been shown that the porosity increases with increasing intensity (gm. per cm.² per sec.) of deposition and also, at any given intensity, with decreasing velocity of deposition of the grains. Thus a very loose packing is achieved either by intense deposition (e.g., free fall in air of a mass of sand) or by slow deposition of single grains in water. In the six sands used in these experiments, only slight differences in porosity could be found between the results given by these two methods. A very dense packing is achieved, not by vibration alone, but by vibration combined with a compressive stress. It is to be noted that the porosity obtained with a high velocity but small intensity of deposition is of the same order as that resulting from simple vibrations.

A.W.S.

996. **The Symmetry of the Potential Tensor in Aerodynamics.**

P. KRIESIS. *Z. Phys.*, **122**, 778, 1944.

Deals with the aerodynamic theory of turbulence. According to viscous fluid theory, infinite potentials should occur when the velocity distribution is unstable. Using the kinetic gas theory the author finds that these potentials are finite, but are transient and unstable as well as unsymmetrical, and that the potential tensor is probably unsymmetrical.

SCI. ABSTR.

997. **The "Floating Thread," a Surface Phenomenon on Flowing Water.**

I. KUŠČER. *Nature, Lond.*, **160**, 673, 1947.

An explanation is given of the appearance of a small elevation, resembling a hair or thread, across the surface of a slowly moving stream of water several feet up stream from an obstacle placed across the stream in its surface.

SCI. ABSTR.

998. **Comparative Evaluation of Viscous Properties of Caustic Magnesite and Caustic Dolomite.**

A. M. KUZNETZOV and N. N. MIKHAILOV. *J. Appl. Chem., U.S.S.R.*, **20**, 257, 1947.

It has been shown that viscous properties of caustic dolomite and caustic magnesite are due to the presence in them of active magnesium oxide and particles of periclase. In baking dolomite, conditions of a total dissociation of magnesium carbonate (at 670° - 700° C.) in a shortest possible time should be created in order to avoid the formation of magnesium oxide particles with their viscous properties lost.

B.C.R.A.

999. **An Electric Flow Meter.**

J. H. LAUB. *Elect. Engng., N.Y.*, **66**, 1216, 1947.

An "electro-caloric" instrument for measuring fluid flow. A tube section with heater coil is inserted in the fluid pipe and thermally insulated by spacers. The temp. difference between two upstream and downstream resistance thermometers is automatically maintained constant by adjusting the power input to the heater coil. This is achieved by a null bridge circuit, an electronic amplifier, and a motor-driven current regulator. Rate of fluid flow is then indicated on a wattmeter and quantity of flow on a Wh-meter. An additional resistance thermometer in the bridge circuit compensates for the variation of fluid sp. heat and viscosity with temp. For large quantities of fluid a by-pass arrangement is used.

SCI. ABSTR.

1000. **Notes on some Canadian Silts.**

R. F. LEGGET and F. L. PECKOVER. *2nd Int. Conf. Soil Mechanics, Rotterdam*, 3, 96, 1948.

A brief description is given of several fluvo-glacial silts occurring on the Canadian Shield, together with a more detailed account of a silt encountered in the bed of Steep Rock Lake on the River Seine 140 miles west of Fort William, Ontario. For mining purposes this lake was drained. The silt was found to be 100 ft. or more in thickness and strongly varied. When undisturbed the silt is stable, excavations being possible with moderately steep slopes and a road having been built on a fill of four feet of sandy gravel, which has carried very heavy construction traffic. Yet on disturbance, as for example after being dumped from the bucket of a dragline, the silt is transformed into a liquid and flows away down gentle slopes in a well-defined stream.

This behaviour is due to the fact that the silt exists, in its natural state, at a water content far above the Atterberg liquid limit; typical values being 75 per cent. and 40 per cent. (on dry weight) respectively. The percentage of particles less than 2 microns varies between 25 and 60, and since these values are unusually high for a soil with a liquid limit of about 40 it is concluded that the surface activity of the colloidal particles cannot be as great as that normally encountered in soils. This is substantiated by electron microscope studies which fail to reveal any of the typical clay minerals. A.W.S.

1001. **On the Connection of the Hardness of a Worked Metal Surface with the Structure Change Incurred during Working.**

K. H. LEISE. *Metallforschung*, 2, 111, 1947.

Comparison of the structure change (grain diminutions) by mechanical working (determined by electron interference) with the increase in hardness (determined with micro hardness tester) by mechanical working in different depths of the worked single crystal surface (Cu, Al, Fe). Comparisons of hardness measurements on Cupal, with those of cold worked surface layers. I.D.I.B.

1002. **On the Temperature Dependence of the Viscosity of Silicate Melts.**

A. LEONT'EVA. *Acta Physicochim. U.R.S.S.*, 22, 279, 1947.

An equation is proposed for the temperature dependence of viscosity, which is satisfied for silicate melts in the range of the viscous liquid state and for molecular liquids, in particular, liquids with homopolar bonds. It is not valid for liquids with ionic bonds, e.g., salts, borax and boric anhydride. B.C.R.A.

1003. **Elastic Moduli and Relaxation Times of Wheat-flour Batters (?) ("Kleikovny Mooki.")**

S. M. LEVI. *Kolloidnyi Zhurnal*, 10 (2), 112, 1948.

Soft sticky doughs (?) batters are found, unlike ordinary firm doughs (Volarovich and Branopol'skaya) to obey Maxwell's relaxation law over periods of relaxation up to 2 min. The elastic moduli calculated from the relaxation experiments agree well with those determined in direct compression and correlate more or less linearly with the quality-score of the dough. The relaxation times are $\sim 1-10$ sec. G.W.S.B.

1004. **Derivation of Stress, Strain, Temperature, Strain-Rate Relation for Plastic Deformation.**

J. D. LUBAHN. *Trans. A.S.M.E.*, p. A229, 1948.

This paper carries out the derivation and correction of an equation previously

presented by J. H. Hollomon and the author, relating to stress for plastic flow (σ), plastic strain (ϵ), strain rate ($\dot{\epsilon}$), and temperature (T).

AUTHOR'S ABSTR. (see Abstr. 877).

1005. General Representation of Velocity Distribution.

F. MAGYAR. *Z. Phys.*, **122**, 640, 1944.

Deals with the velocity distribution of fluid flow in pipes. The velocity distributions according to v. Kármán and others do not yield continuous functions showing the transition of flow near the middle of the pipe to the laminar flow close to the walls. The author develops an expression which gives the velocity distribution from the centre to the walls as a continuous curve, and agrees well with measurements.

SCI. ABSTR.

1006. Instrumentation Studies.

S. G. MASON and M. TUCK. *Quarterly Report of Pulp and Paper Inst. of Canada*, Sept.-Nov., 1947., p. 3.

It has been shown that for a given gauge in the Mullen tester, the rate of change of pressure at the instant of burst is proportional to the burst pressure for a variety of papers. The proportionality constant depends upon the gauge, and is believed to be determined largely by the "compressibility" of the gauge coil. Compressibilities of various types of gauges have been measured and found to vary from 7×10^{-4} to 7×10^{-3} cc./psi. Analysis of the pressure-time curves in the bursting of paper obtained from motion pictures of gauge dials have shown that in properly adjusted gauges two basic types of errors can occur. These are vibrational and lag errors arising respectively from the inertia and friction of the moving parts of the gauge mechanism. Additional errors have been detected in improperly adjusted gauges. Curiously enough "overshooting" errors which have been believed to occur by a number of observers, have not been detected even when gauges have been purposely adjusted to favour their occurrence. A dynamic deadweight tester has been devised to carry out gauge calibrations under the same conditions of loading as in the bursting of paper and to determine the relative importance of the various types of error. In addition to providing a convenient method of gauge calibration it is now believed that the results of this study can be used to draw up a more rigid specification for the gauge and other components of the burst tester.

P.A.T.R.A.

1007. Branched-Chain High Polymers.

H. W. MELVILLE and G. W. YOUNGSON. *Nature*, **161**, 803, 1948.

The communication describes attempts to synthesize, characterize and measure the properties of branched chain super ester molecules from the copolymerisation of penta erythritol or similar substance with ethylene glycol and adipic acid and stopping just short of the gel point. Graphs are given relating $[\eta]$ of solutions of the polymers in chloroform as a function of molecular weight. These are not linear and the maximum value of $[\eta]$ found was 0.6 (Einstein value 2.5). Branching in a high-polymer molecule is unlikely to be easily detected from $[\eta]$ measurements, since with m.w.s. of 10,000 to 20,000, $[\eta]$ was similar to that for linear polymers.

E.W.J.M.

1008. Effect of Natural Hardening on the Unconfined Compression Strength of Remoulded Clays.

O. MORETTO. *2nd Int. Conf. Soil Mech., Rotterdam*, **1**, 137, 1948.

Four clays were sampled in the field, and their compression strengths determined. On remoulding at constant water content the strength was reduced to values lying

between 10 and 30 per cent. of that of the undisturbed specimens. These reductions are quite typical for sedimentary clays.

The remoulded clays were then placed in glass moulds, sealed in paraffin wax, and left for varying periods. Tests made from time to time showed a progressive increase in strength, ranging from 150 to 320 per cent. after 60 days, and in two clays, from 210 to 440 per cent. after 600 days.

It was not possible to maintain absolutely constant water content, but it is considered that the slight changes (less than 2 per cent.) could not account for any significant proportion of the observed increase in strength. This increase is ascribed to thixotropy, which therefore appears to be more important than irreversible structural breakdown, in this well known phenomenon of a loss in strength of sedimentary clays caused by remoulding. A.W.S.

1009. Partially Plastic Thick-walled Tubes.

C. W. MACGREGOR, L. F. COFFIN and J. C. FISHER. *J. Franklin Inst.*, **245**, 135, 1948.

A theory is presented for the partial plastic yielding of thick-walled cylindrical tubes acted upon by any combination of internal pressure, external pressure and end load when the material follows an arbitrary stress-strain law. The solution combines (a) the distortion energy theory of plastic flow and (b) the effects of elastic compressibility of the plastic material. Numerical values for stresses and strains are given for certain special cases of internal pressure in thick-walled open-ended tubes for an idealized stress-strain law, and the results are compared with earlier approximate theories. SCI. ABSTR.

1010. The Chemistry and Rheology of Clay.

G. NAGELSCHMIDT, M. C. MACEWAN, E. W. J. MARDLES and H. H. MACEY. *Nature, London*, **160**, 511, 1947.

Condensation of hexagonal nets of silicon-oxygen tetrahedra with nets of similar mesh-size of aluminium, magnesium or iron-oxide tetrahedra leads to the arrangement in the kaolin group. Kaolinite is triclinic and strictly periodic in three dimensions, but there is random arrangement of the structural units along *a* and *b* in halloysite, and certain plastic sedimentary clays of the kaolin type are intermediate. Condensation of two tetrahedral layers with one octahedral layer between gives the arrangement in mica and montmorillonite. Isomorphous replacements occur widely in both, causing variability in chemical composition and, by introducing a large negative charge, produce the higher base-exchange capacity of the latter. The new clay mineral technique shows that most clays and soil colloids are mixtures of clay minerals, often with oxides, hydroxides and carbonates. Halloysite and montmorillonite are random structures similar to some organic polymers, but are planar rather than chain polymers. Adsorption of organic molecules by montmorillonite is a type of polar adsorption, and can be arranged in thicknesses of from one to three layers. X-ray diffraction data may show many orders of the basal reflexion, so that a one-dimensional Fourier distribution can be developed. The consistency, yield value and thixotropy of kaolin vary from liquid to liquid according to the dispersive power, which appears to be closely related with the degree of wetting of the kaolin. With the addition of a small amount of soluble colloidal substance, such as a resin derivative, the character of the clay dispersion changes in great measure to that of the colloid itself. Neither theory of the structure of plastic clay is entirely satisfactory, although that of the replacement of a rigid water film round the clay particles in earlier theories by a potential field between opposing clay surfaces, whereby those surfaces appear to repel one another, is preferred by the author, giving a more logical interpretation of rheological properties, such as shear hardening. Differences in plasticity become associated with differences in particle size, distribution and packing. B.C.R.A.

1011. A Statistical Analysis of some Mechanical Properties of Manila Rope.

S. B. NEWMAN and J. H. CURTISS, *J. Res. Nat. Bur. Stand., Wash.*, **39**, 551, 1947.

Breaking strength, weight and circumference are three important qualities that are determined when ropes are submitted for test. These properties are all subject to some variation because of differences in fibre quality, method of fabrication, and previous treatment. The results of tests on more than 800 samples of 3-strand manila ropes ranging in size from $\frac{1}{16}$ in. to 3 in. in diameter are tabulated and analysed by the methods of modern mathematical statistics. Considerable emphasis is placed on the rationale and details of the methods of analysis, as they are considered to be applicable to a broad variety of similar projects. SCI. ABSTR.

1012. Stressed Aluminium.

E. A. OWEN, T. H. LIU and D. P. MORRIS. *Nature*, **161**, 681, 1948.

After the release of compressional stress on aluminium (purity 99.998%), the lattice parameter which had increased, decreased exponentially with time finally reaching a value higher than the equilibrium value. Reflection photographs showed that after compression, recrystallization took place, the rate of recrystallization increasing with compression; with very severe compression, recrystallization occurred rapidly and immediately after stress release. Foreign atoms hindered recrystallization and grain growth. Polishing and filing produced the same metastable state in the surface as severe cold-work produces throughout the body of the material. E.W.J.M.

1013. Physical Problems Raised by the Glass Fibre.

I. PEYCHÈS, *Mém. Soc. Ing. Civ. France*, **98**, 411, 1945.

A mainly mathematical treatment of the behaviour of glass when formed into threads from the molten state through a jet, by mechanical methods, centrifugal force, or by fluid flow. The filament-forming capacity is measured by η (poises)/ γ (dynes/cm.), and it rises from 0.33 at 1,400° to 6.5 at 1,100° and 26 at 1,000°. A low temp. gives a fine filament, but a low throughput. The Young (Y) and rigidity (R) moduli of a glass filament both decrease with a reduction in the fibre diameter (D); when $D > \sim 30\mu$ the Poisson coeff. falls, indicating the development of anisotropic conditions. Thermal treatment of the filaments restores R and Y to the values characteristic of glass in bulk. The flexing resistances of glass fibres of relatively high (0.1 – 0.8 mm.) and low (10 – 80 μ) D , increase with increase in D linearly and as a hyperbolic function, respectively. SCI. ABSTR.

1014. Thermally Reversible Strains in Plasticised Polyvinyl Chloride.

W. F. O. POLLETT. *J. Soc. Chem. Ind.*, **60**, 319, 1947.

Torsion tests have been used to investigate the strain in relation to the conditions under which it is produced. The initial set, on cooling after release of the applied strain, increases with the time, temperature and extent of deformation and rapidity of cooling, but under the experimental conditions was almost wholly recoverable on re-heating. Cooling under strain increases the initial set, and recovery then begins at the commencement of re-heating; otherwise it starts at a higher temperature the slower the cooling after release. Recovery per unit temperature rise reaches a maximum just below the straining temperature, at a position depending on straining time and rate of cooling, but not on composition within wide limits. Even opposed strains introduced successively at diminishing temperatures are separately recoverable on re-heating. A qualitative explanation of the phenomena is proposed which assumes the presence of associations covering a wide range of stabilities. SCI. ABSTR.

1015. A New Method for the Measurement and Control of Consistency of Thin Stock in Pulp and Paper Mills.

W. F. PRAY. *Instruments*, **20**, 539, 1947.

To determine the viscosity of pulp and paper in the range below 1½% consistency, advantage was taken of the fact that consistency had an effect on the drainage rate of the stock when laid on a wire or perforated cylinder. This characteristic, called drainage rate for want of a better term, depends on a combination of consistency and freeness, plus some minor and undetermined variables. B.C.R.A.

1016. Hydrodynamics of non-Newtonian Fluids.

R. S. RIVLIN. *Nature. Lond.*, **16**, 611, 1947.

General stress/strain-velocity relations of incompressible fluids have been applied to two cases of the shear motion of cylindrical masses of fluid; forces are found to be necessary on the ends of the cylinders, if the fluids are non-Newtonian. SCI. ABSTR.

1017. Large Elastic Deformation of Isotropic Materials. I. Fundamental Concepts. II. Some Uniqueness Theorems for Pure, Homogeneous Deformation.

R. S. RIVLIN. *Philos. Trans. A.*, **240**, 459, 491, 1948.

I. Components of strain and stress are defined in the case of large deformations; and a type of stress/strain relationship (called neo-Hookean elasticity) is studied in detail. Incompressibility of the material is assumed. This relationship is used as a basis for a theory of large elastic deformations, and it agrees with that obtained, for an ideal rubber-like material, from molecular statistical considerations. The stored energy formula is obtained, and the equations of motion are derived (by a variational method). These are given both in terms of the stress components and in terms of the stored energy function. The results are equivalent. II. The equilibrium of a cube under the action of 3 pairs of equal and opposite normal forces is studied. Various conditions are found in order that the equilibrium state be unique. SCI. ABSTR.

1018. Large Elastic Deformations of Isotropic Materials. III. Some Simple Problems in Cylindrical Polar Co-ordinates.

R. S. RIVLIN. *Philos. Trans. A.* **240**, 509, 1948.

General results obtained earlier are specialized to the case of axial symmetry and applied to the simple torsion of a solid of a solid cylinder and of a hollow cylindrical tube and their combined simple extension and torsion. For a solid cylinder, simple torsion may be maintained by surface tractions consisting of a torsional couple and a compressive force applied to the ends of the cylinder. For a hollow cylindrical tube it is necessary to apply, in addition, a normal surface traction on one of the curved surfaces of the tube. SCI. ABSTR.

1019. How to Develop Maximum Strength in Alloy Steel Bolts.

G. SACHS. *Steel*, **122**, 104, 1948.

This digest is based on a paper to the American Institute of Bolt, Nut and Rivet Manufacturers, reporting an investigation designed to clarify some of the factors which might cause embrittlement of high-strength alloy-steel bolts. Bolts fabricated from S.A.E. 2330 steel were used in the tests made.

Since it had been observed that various forms of bolt failure occurred under

varying conditions, principally breaks through the threads and under the head, a variety of bolt designs was tested :—standard bolts, bolts reduced in section at various points, and bolts with an increased radius machined under the head. Four different strength-characteristics of the 2330 steel in various conditions of heat-treatment were thus determined ; strength through the thread ; strength under the head ; strength through the notched section, and ultimate strength of a reduced cylindrical section.

On the basis of the data reported, suggestions are made for lessening risk of failure.

NICKEL BULL. (see Abstr. 495).

1020. Graphite Lubrication.

R. H. SAVAGE. *J. Appl. Phys.*, **19**, 1, 1948.

The slipperiness of graphite is not inherent in the crystal structure alone but depends upon adsorption films, especially water, which cover the carbon atoms and provide surfaces of low cohesion. In vacuum graphite rods or brushes seize upon moving base (copper or graphite) and wear away as a fine dust. This wear and the accompanying high friction are instantly stopped by some condensable vapours at low pressures (H_2O , C_6H_6 , NH_3 , etc.) which apparently effect the coverage of the graphite by a reversible adsorption governed by the pressure and surface temperature. Under conditions of optimum coverage (zero wear) the graphite friction is still appreciable but may be accounted for as the heat of cohesion of water monolayers attached to the carbon atoms and undergoing successive makes-and-breaks. From the measured frictional energy and an assigned heat of cohesion based upon surface energy data, the area of molecular contact is estimated to be $4 \times 10^{-6} \text{ cm}^2$, under a real pressure of $2 \times 10^4 \text{ kg./cm}^2$.

The wear dust of unlubricated graphite shows a unique absorptive power at room temperature greater for hydrogen than that of activated charcoal by five orders of magnitude. This and other characteristics may throw new light upon the mechanism of friction in general and upon the structure of stroked graphite surfaces in particular.

L.R.G.T.

1021. The Wire Resistance Strain Gauge.

P. SAVIC. *Research, Lond.*, **1**, 98, 1947.

Various strain gauge resistance materials are compared. The resistance change due to strain is due not only to dimensional alteration of length and cross-section, but the resistivity itself is a function of the strain. The gauge sensitivity is independent of gauge length. Cementing the gauges to the test piece is discussed. Two cements are usual, (a) cellulose acetate which is affected by water absorption, and (b) thermosetting plastics which suffer from creep when hot. The errors due to these defects are studied. Various gauge circuits are described. D.c. bridge schemes or a.c. with amplifiers are employed. To show the sign and magnitude of strain when using a.c., a special phase discriminator is used. Some strain gauge applications are mentioned.

SCI. ABSTR.

1022. Statistical Theory of Macromolecular Solutions. II. Entropy of Mixture and Osmotic Pressure of Solutions of Elongated Rigid Particles. III. Elongated Particles with Inner Mobility.

G. V. SCHULZ. *Z. Naturforsch.*, **2a**, 348, 411, 1947.

It is shown from statistical calculations that the entropy of mixtures, and therefore the osmotic pressure, in solutions of elongated particles, is considerably higher than in solutions of spherical particles. The effect is found to be dependent entirely

on the axis relationships of the particles, and the relevant mathematical equations are derived for a cylindrical model. Satisfactory agreement is found with some experimental data which have been obtained for axis relationships from sedimentation velocities in the ultra-centrifuge for molecules of serumglobulin and myosin ; and from osmotic measurements. In Part III, the mixture entropy of solutions of fibre molecules with internal mobility has been derived by a molecular statistical method based on a molecular model. The latter is composed of a number of rigid members in a linear arrangement, each of which can move entirely independent of the others ; and the greater the inner mobility of a fibre molecule, the more the number of members in the model. The calculation indicates that the entropy of mixture, and therewith the osmotic pressure, is greater than corresponds with the ideal law, and this enhancement has been determined from the ratio of the length to the cross-section of the single members of the model. Fibre molecules, with perfectly freely unhindered rotations, exhibit an ideal entropy of mixture, and their osmotic pressure obeys the van 't Hoff law, when their heats of dilution are zero. Only one example of experimental data is to be found in the literature, viz., of guttapercha in toluene, and here the results are in fairly good agreement with the calculations. For solutions with finite values of their heats of dilution (positive or negative), it is not possible as yet to gain information as to the shape of molecules from osmotic measurements.

SCI. ABSTR.

1023. Physical Measurements in the Dairy Industry.

G. W. SCOTT BLAIR. *J. Soc. Dairy Technol.*, **1**, 180, 1948.

A short survey of the principles involved in physical and psycho-physical testing in the dairy industry, mainly rheological.

G.W.S.B.

1024. A Study of the Triaxial Test on Cohesive Soils.

A. W. SKEMPTON. *2nd Int. Conf. Soil Mech., Rotterdam*, **1**, 192, 1948.

A theoretical analysis of the compression strength of saturated clays, tested in the triaxial apparatus under conditions of no water content change, is presented. The compression strength is shown to be

$$(\sigma_1 - \sigma_1) = 2 \left\{ \frac{c_e \cos \varphi_i + p \sin \varphi_i}{1 + \sin \varphi_i \frac{1 - 2\lambda}{1 + 2\lambda}} \right\}$$

where c_e and φ_i are the true cohesion and angle of internal friction of the clay at the water content of the specimen, p is the pressure under which the specimen has been consolidated either in nature or in the laboratory, and λ is the ratio of the expansibility and the compressibility of the clay structure. For soft, normally consolidated clays λ is approximately zero while for stiff clays λ approaches or may exceed unity.

The angle of friction φ_i can be deduced from the inclination of the shear planes or Luders' lines in a compression specimen and thus is the strength of a clay which has been consolidated under a known pressure p is measured, the cohesion can be deduced : since λ can be assigned a reasonable value or directly measured by a separate experiment.

Values of φ_i for 20 clays are given, from which it appears that, for clays of the same general mineralogical group, there is a moderately close relationship between φ_i and porosity.

A.W.S. (see Abstr. 293).

1025. **On the Problem of Refining the Solutions of Reynolds' Equations.**
N. A. SLEZKIN. *C.R. Acad. Sci. U.R.S.S.*, **54**, 121, 1946.

Plane steady motion in a layer of a viscous incompressible fluid is considered. The exact equations of motion are written down, and from these the equations of Reynolds and of Prandtl may be deduced. The solutions may be written in the form of a series, but from the third approx. onwards both variation of pressure along the thickness of the layer and the viscosity terms must be considered. SCI. ABSTR.

1026. **The Generalized Equations of Reynolds.**

N. A. SLEZKIN and S. M. TARG. *C.R. Acad. U.R.S.S.*, **54**, 205, 1946.

The equations describe the motion of a viscous fluid and are intermediate between those of Reynolds, occurring in the approx. theory of lubrication, and those of Prandtl, in which quadratic inertia terms are present. They are obtained from Prandtl's equations by averaging over the thickness of the layer of viscous fluid. A formula for the pressure distribution is obtained. SCI. ABSTR. (see Abstr. 914).

1027. **Colloidal Graphite in Assembly Lubrication.**

E. A. SMITH. *Engineering*, **165**, 505, 1948.

Contour determinations of polished and turned surfaces reveal the surfaces as a series of jagged peaks and hollows. Thus when two surfaces are in contact, only a fraction of the total surfaces is actually bearing the load. When one of the surfaces starts moving very high local loads and temperatures operate on the tips of the asperities. These loads and high temperatures make it impossible for a film of a lubricant to separate the surfaces completely or to lubricate them. Local breakdown would occur under these conditions, e.g., the starting of newly assembled bearing surfaces. The lubricant would then tend to spread and re-cover the surfaces. The rate of spreading depends on many factors, one of which is the adsorption of the oil, or parts of it, on the surface. Simultaneously, with these events taking place in the oil film, metallographic changes occur in the rubbing surfaces. These changes are markedly influenced by the degree of finish of the surfaces and by the direction of the finish marks compared with the direction of motion.

Colloidal graphite helps to reduce the worst effects of all the phenomena discussed. As the graphite particles are held on the high spots they prevent metallic pickups. By being adsorbed they stimulate wetting of the surface by the oil and increase the spreading rate of the oil. Experiments show that the rate of spreading of an oil over chromium surfaces buffed with colloidal graphite was five to six times the rate over untreated surfaces. In other experiments the oil was shut off and the bearings were allowed to run to destruction. With graphited oil the bearing ran for 181½ hours whilst on plain oils the bearings ran for only a few, not exceeding 5, hours.

Graphite may be applied in one of three ways: (1) it may be burnished on the new face; (2) it may be painted or sprayed, or (3) it may be applied in the oil.

A.H.N.

1028. **Reconsideration of the Theory of Free Turbulence.**

H. B. SQUIRE. *Phil. Mag.*, **39**, 1, 1948.

Dimensional analysis is applied to various problems of free turbulence, e.g., the wake of a symmetrical cylinder, or a body of revolution, the plane and round jets, and a wake of a row of rods. No hypothesis about the nature of turbulent flow is made. The various theories of turbulent flow are then discussed. These include the momentum transfer theory, the vorticity transfer theory, Karman's similarity theory and Reichart's theory. The report concludes with a note on wall turbulence: the deduction of the logarithmic velocity distribution near a wall. SCI. ABSTR.

1029. Stiffness Testing of Paper.

B. STEENBERG. *Finnish Paper Timber J.*, **29** (7A), 61, 1947; *Bull. Inst. Paper Chem.*, **18**, 391, 1948.

Paper exhibits simultaneously elastic and plastic properties, a fact which must be taken into consideration in stiffness measurements. The deflection of a sheet of paper subjected to load increases with time, because of the viscous flow in the material. Since flow of paper sets in almost immediately, rigidity, modulus of elasticity, etc., cannot be determined from static experiments by applying Hooke's law. In investigations concerning purely elastic components in paper, bending must be followed at once by relaxation in order to eliminate flow. Pure elastic stiffness has been determined by means of a stiffness tester, in which a test strip clamped at one end is vibrated 50 times per second perpendicularly to the plane of the paper, and the length of the strip varied until the paper is in resonance with the oscillations. The paper then behaves like a tuning fork, and from known formulae the elasticity and rigidity can be calculated. The bending is too rapid to allow flow and, since the deflections are small, the application of Hooke's law is justifiable. Studies with this instrument and the empirical instrument designed by Clark (*TAPPI Standard T451 m-45*) showed that both instruments measure the same property and Clark's instrument can thus be calibrated in c.g.s. units. Studies on paper stiffness showed that this property is determined not only by fibre orientation but also by the stretch on the paper machine. The relation between the ultimate strengths in the machine and cross-machine directions depends in many cases on this stretch. The author suggests that the strength properties of paper are governed to a considerable extent, not by the orientation of the fibres, but by the orientation of the cellulose molecules in the contact areas between the fibres. A stretch which is not sufficient to increase the orientation of the fibres may still be large enough to influence the orientation of these shorter elements. P.A.T.R.A. (see Abstr. 816, 918.)

1030. Cross-Laminated Oak.

E. G. STERN. *Trans. A.S.M.E.*, p. 123, Feb., 1948.

Three-ply cross-laminated oak panels with oak or yellow-poplar core of $\frac{25}{32}$ or $1\frac{1}{4}$ in. total thickness, and 7 x 7 in., or 12 x 12 in. in area, were subjected to exposure tests of repetitive and/or alternating drying at slightly below 100° C., and/or soaking at laboratory temperature for 48 hours, in order to determine the influence of internal stresses due to exposure on the dimensional stability and durability of such panels. The test results indicate that these panels can be cross-laminated satisfactorily to withstand extreme exposure conditions such as may occur in service, if their cross sections are properly balanced and their plies are properly assembled. The Tennessee Valley Authority designed and built a continuous-press pilot plant for the production of these 12-in. wide panels of any desirable length.

AUTHOR'S ABSTR.

1031. A Coefficient of Viscous Extension.

K. H. SWAINGER. *Nature*, **161**, 650, 1948.

A generalized theory on straining of amorphous solids can include the straining of viscous fluids by means of a suitable stress-strain parameter λ , the coefficient of viscous extension, related to the coefficient of viscosity. The Author considers only the flow strain component of a deformed substance (isotropic) neglecting the elastic and plastic components, when λ is analogous to Young's modulus and is a non-constant tangent modulus if the substance is quasi-viscous. The transverse contraction ratio will have the value $\frac{1}{2}$ in solids as well as liquids if volume changes do not occur: however the static "plastic" transverse contraction ratio value 0.36 was found for duralumin. E.W.J.M.

1032. **An Optical Rectangular Rosette Extensometer for Large Strains.**
K. H. SWAINGER and J. TWYMAN. *J. Sci. Instrum.*, **25**, 187, 1948.

In this extensometer a third leg has been added which makes an angle of 45° with the other two. This enables strains in three directions about a point to be measured. A special clamp for attaching the extensometer to the test specimen allows large strains to be measured. J.E.C.

1033. **A Simple Theory of Static and Dynamic Hardness.**

D. TABOR. *Proc. Roy. Soc. A.*, **192**, 247, 1948.

The last stage of the indentation of a softer metal surface by a hard spherical indenter is elastic, and is found to be reversible, repeatable and to conform to Hertz's equations for the elastic deformation of spherical surfaces. The energy of elastic recovery accounts for the energy of rebound of the indenter in dynamic hardness tests; where, with soft metals, the dynamic hardness $\gg$ the static, it is suggested that quasi-viscous forces, dependent on time, must be taken into account. It is shown experimentally that for a material incapable of appreciable work-hardening, the mean pressure $\bar{P}_m$ required to produce plastic yielding is related to the elastic limit Y of the material by a relation $\bar{P}_m = c Y$, where c is a constant having a value between 2.6 and 3. An empirical method is described which takes into account the work-hardening produced in metals by the indentation process itself. This results in a general relation between hardness measurements and the stress-strain characteristic of the metal, and there is close agreement between the theory and the observed results. In addition, the theory explains the empirical laws of Meyer. SCI. ABSTR.

9034. **On Theory of a new Method for Determining Young's Modulus.**

V. L. TALEKAR. *Curr. Sci.*, **16**, 337, 1947.

Proposes measurement of the change in radius of a current-carrying loop of wire on establishing a strong magnetic field perpendicular to the plane of the loop. SCI. ABSTR.

1035. **A Combined Creep Machine and X-Ray Spectrometer.**

H. J. TAPSELL, H. V. POLLARD and W. A. WOOD. *J. Sci. Instr.*, **25**, 198, 1948.

An apparatus is described which enables an X-ray examination of a specimen to be made whilst it is being subjected to a creep test at constant stress. J.E.C.

1036. **Application of Relative Motion about the Centre of Gravity to a Formula concerning Global Discharge in a Tuyère.**

T. TESSON. *C.R. Acad. Sci., Paris*, **225**, 796, 1947.

Application of the principle of the conservation of energy to the relative motion of a fluid particle about a point coinciding at time t with the c.g. of the particle is shown to lead to a general deduction of fluid discharge in a tuyère. A particular case of the general result now deduced is given by Stodola. SCI. ABSTR.

1037. **Measurement of Stress by means of X-Rays.**

D. E. THOMAS. *J. Appl. Phys.*, **19**, 190, 1948.

The article shows how the formulae used in stress measurements by X-ray are derived and points out an error in a recently published book. SCI. ABSTR.

1038. **Influence of Water on the Lubrication of Metals.**

E. D. TINGLE. *Nature, Lond.*, **601**, 710, 1947.

Lubrication of freshly exposed metal surfaces (Cu, Cd, Mg) by fatty acids was found to be ineffective until the surface has been in contact with water or water vapour and dried. This confirms the chemical character of attachment of the lubricating layer and indicates that a loose hydroxide or hydrated oxide plays a part.

SCI. ABSTR.

1039. **On Wall-Slippage Effects in Dispersed Systems.**

D. M. TOLSTOI. *Kolloidnyi Zhurnal*, **10** (2), 133, 1948.

A study of friction between sliding blocks and of the rheology of lubricants under these conditions by comparison with the surface rheology as determined by Deryagin's "Blow-off" method.

G.W.S.B.

1040. **The Flow of Gases and Vapours through Adsorbing Porous Media.**

R. H. TOMLINSON and E. A. FLOOD. *Canad. J. Res. B.*, **26**, 38, 1948.

The flow rates of gases and vapours through highly activated charcoal rods have been measured. The results obtained indicate that a new phenomenon has been discovered. While the flow rates of gases that are not highly adsorbed can be satisfactorily correlated by the Adzumi and other similar equations, the strongly adsorbed vapours of diethyl ether and ethyl chloride pass through at rates considerably > those required by known equations. It appears necessary to resort to mechanisms quite outside those usually considered in the application of kinetic theory to problems associated with passage of gas through porous diaphragms. The simplest and most direct of such mechanisms involves mobility of the adsorbed material. The flow rate of diethyl ether through activated charcoal rods has been found to be > that of He in pressure regions where relative rates of flow of gases through non-adsorbing porous diaphragms are dominated by inverse square root molecular weight ratios. The measurement of gaseous flow rates through porous media is rendered the more difficult where appreciable adsorption occurs. The experimental methods are described in detail, sources of error are discussed and results presented for He, H₂, N₂, CO₂, diethyl ether, and ethyl chloride.

SCI. ABSTR.

1041. **Expansion Effects shown by some Pyrex Glasses.**

A. Q. TOOL and J. B. SAUNDERS. *J. Res. Nat. Bur. Stand., Wash.*, **40**, 67, 1948.

Thermal expansion data are presented, which apparently confirm a previously expressed belief that some of the borosilicate glasses containing a high percentage of silica are essentially 2-component glasses. One of these components is presumably composed almost entirely of silica and forms into a comparatively rigid and continuous spatial network that pervades the whole glass. This formation develops before the glass is cooled into the annealing range of the other component which is composed of a portion of the silica and most of the other constituents. On being cooled into its annealing range and particularly on reaching temperatures below this range, the low-temperature component also forms a fairly rigid network which is interlaced with that of the high-temperature component. The latter, being composed mainly of silica, possesses a considerably lower expansivity than the other. Consequently, the low-temperature component, whenever it behaves as a rigid network, elastically compresses the other component on cooling and is, in turn, elastically distended. Annealing the glass at suitable temperatures relaxes the compressions and distensions. Such relaxations cause expansions and contractions that are unlike those found in a normal single-component glass. As a result, thermal expansion

sion cycles obtained on glasses containing a high percentage of silica show certain peculiarities. Several cases in which these appear are presented and discussed.

SCI. ABSTR.

1042. **The High-Temperature Fatigue Strength of Several Gas-Turbine Alloys.**

P. R. TOOLIN and N. L. MOCHEL. *Advance Print A.P.9 (with discussion)*, from *Proc. A.S.T.M.*, **47**, 1947.

An extensive programme of high-temperature fatigue-testing has been in progress in the Westinghouse Research Laboratories for several years, in collaboration with the War Metallurgy Committee and other organizations. This paper summarizes the results to date.

All the tests reported were made on the Westinghouse 120-cycle electromagnetic bending-fatigue machine, of which a diagram is given in the paper. The specimens used are also illustrated.

Results are classified in the six groups of alloys shown below. The materials given in brackets after the class indicate the individual materials of the group for which data have been obtained.

(1) *Chromium-Nickel-Cobalt Alloys* (Midvale GTA; S816; rolled Vitallium; N155 low- and high-carbon; N153; S590; S497; Timken No. 2).

(2) *Nickel-Molybdenum Alloys* (Hastelloy B).

(3) *Nickel-Chromium and Nickel-Chromium-Cobalt Alloys, Titanium- and Aluminum-Hardened* (Inconel X); 80-20 nickel-chromium; K 42 B; Inconel W; Nimonic 80; Refractaloy 26).

(4) *Nickel-Chromium-Iron Alloy* (Timken 16-25-6); S495; 17 low-carbon disc alloy; Hoskins 502; GT45; 17W, high carbon; Gamma Columbium; 25-20 and 25-12 chromium-nickel-iron alloys).

(5) *Chromium-Nickel-Iron Alloys* (19-9 DL; 234 A5; 18-8 W-Mo; 19-9 W-Mo).

(6) *Precision-Cast Alloys* (6059; X 40 or Stellite 31; Vitallium; 61 or Stellite 23; 19-9 W-Mo; S495; 25-20 chromium-nickel-iron; S816).

Individual results are tabulated and graphed and summary tables give composition and fatigue-strengths of the twelve alloys showing highest values for 100 million cycles at (a) 1200° F.; 648° C. and (b) 500° F.; 260° C. At 1200° F. the figures range from 71,000 p.s.i. (31.7 tons per sq. in.) to 50,000 p.s.i. (22.3 tons per sq. in.).

The alloys showing highest fatigue-strength at 1500° F. vary over a relatively wide range of composition, indicating that other factors may play an important part, and results obtained by Westinghouse tend to show that maximum fatigue- and creep-resistance are not always closely associated. The wrought form of an alloy appears to have higher fatigue-strength, at the temperatures used in these tests, than the precision-cast form.

NICKEL BULL. (see Abstr. 793).

1043. **A Sound Velocity Method for determining the Compressibility of Finely Divided Substances.**

R. J. URICK, *J. Appl. Phys.*, **18**, 983, 1947.

A method is presented whereby the adiabatic compressibility of a finely divided material can be found from sound velocity and density measurements of a suspension of the particles in a liquid. It is based on the assumption that the velocity of sound in a suspension is the same as it would be in an ideal solution of the two substances. This is verified experimentally by measurements on kaolin-water suspensions and xylene-water emulsions, and the method is illustrated by the determination of compressibility of the oil droplets in an oil emulsion and of the blood corpuscles in horse blood. Considerable accuracy is attainable for materials which are not too incompressible compared to the suspending liquid.

SCI. ABSTR.

1044. **Some Remarks on Eyring's Theory of Viscous Flow.**

P. F. VAN VELDEN. *Physica's Grav.*, **13**, 529, 1947.

It is concluded that the difference between the experimental quantity :

$$E_{vis} = R \cdot d(\ln \eta)/d(1/T)$$

and Eyring's "energy of activation for viscous flow" (U^*) cannot be neglected, as has been done in previous work. For many compounds E_{vis} has been found to be independent of temperature over the ranges measured. It appears to be impossible to explain this on the basis of Eyring's theory. SCI. ABSTR.

1045. **Capillary-Tube Viscometer for Routine Measurements of Dilute High-Polymer Solutions.**

R. H. WAGNER and J. RUSSELL. *Anal. Chem.*, **20**, 151, 1948.

A capillary-tube viscometer is described which is particularly suited for the routine measurements of dilute high-polymer solutions. Its design minimizes the time required for the measurement, including the necessary operations of filling, cleaning and drying the viscometer. Consideration is given to errors, including those produced when the differences in densities and velocities of flow (kinetic-energy correction) of the solvent and solution are neglected. AUTHORS' ABSTR.

1046. **Applications of Corrections in Viscometry of High-Polymer Solutions.**

R. H. WAGNER. *Anal. Chem.*, **20**, 155, 1948.

The importance of the relative densities and of the so-called kinetic-energy correction in the measurement of the relative viscosities of polymer solutions is discussed. Equations are derived relating the separate and combined contribution of these factors to the relative viscosity and to the inherent viscosity, an important polymer-characterizing function. A nomograph is presented by means of which the kinetic-energy correction contribution may be easily and quickly evaluated. AUTHOR'S ABSTR.

1047. **The Theory of Rate Processes and the Viscosity of Long-chain Compounds.**

W. C. WAKE. *Trans. Faraday Soc.*, **43**, 708, 1947.

An attempt is made to give more precision to the interpretation of the energy of activation for viscous flow which occurs in Eyring's theory. Particular attention is paid to the effect on this energy of the "holes" already present in the liquid structure. From the force fields between molecules the energy required to form holes is calculated for long-chain paraffins, and this, together with the experimental evidence concerning the size of the moving segment in flow, leads to estimates of the activation energy in fair agreement with observed values. L.R.G.T.

1048. **A Constant Stress Apparatus for the Study of the Creep Properties of Plastics.**

A. G. WARD and R. R. MARRIOTT. *J. Sci. Instr.*, **25**, 147, 1948.

The apparatus is essentially that of Andrade and Chalmers, but with the profile of the cam computed numerically. The extensions were recorded optically giving two ranges one of which enables very slow extensions to be recorded. Particular attention has been given to the method of applying the load to avoid the specimen oscillating. Some examples of stress-strain curves are given for a nitrocellulose plastic. J.E.C.

1049. Note on the Notion of Long-Distance Order applied to the Velocity Distribution in Liquids.

J. WINTER. *C.R. Acad. Sci., Paris*, **225**, 859, 1947.

The author proposes to extend the notion of long-distance order as established in the theory of super-lattices to the velocity distribution in liquids where the transition from laminar to turbulent flow corresponds to the order-disorder transition. The suggested treatment should consist in a consideration of the interaction of adjacent filaments of liquid on a wave-mechanical basis. The movement of a filament would be represented by certain eigenfunctions which are perturbed by the other filaments. From the properties of the Mathieu functions which would appear in a periodical perturbation field, disturbance of the long-distance order at conditions similar to the well-known turbulence conditions is foreseen. SCI. ABSTR.

1050. The Use of Electric Resistance Wire Strain Gauges in Static Strain Measurements.

W. H. WITTRICK. *J. Instn. Engrs. Aust.*, **19**, 165, 1947.

Construction and properties of the gauges, and their practical application in the testing laboratory, are described. The strain sensitivity is shown to be independent of the length of the gauge wire. Calibration technique and instrumentation methods suitable for multiple-point measurements are discussed. Null-point and direct reading circuits can be used. The latter are best used in conjunction with d.c. amplifiers and automatic recorders. Practical recommendations for performance tests are given. SCI. ABSTR.

1051. The Behaviour of the Lattice of Polycrystalline Iron in Tension.

W. A. WOOD. *Proc. Roy. Soc. A.*, **192**, 218, 1948.

The stress-strain characteristics have been investigated for two distinct types of lattice plane in specimens of Swedish iron in tension. Earlier observations are confirmed that the metallic lattice under stress ceases to conform with Hooke's law when external plastic deformation occurs, but the deviation differs in the two cases. The elastic range for the (211) spacing appears to be $>$ for the (310) spacing. On removal of stress in excess of the "lattice yield," the two types of spacing show a residual strain of opposite sign to the strain under stress, but the magnitude is different. The residual strain is attributed to the onset of internal stresses as a result of plastic flow, and the difference in strain for the different types of plane to a difference in magnitude of the internal stress for grains of different crystallographic orientation. The internal stresses for both types of plane appear to consist of a longitudinal compression and a transverse compression. These components should be balanced by equivalent regions in tension, but none so far have been found. It may be necessary to conclude that such regions are in a state too disordered for coherent reflection. SCI. ABSTR.

1052. Internal Stresses in Metals.

W. A. WOOD and N. DEWSNAP. *Nature*, **161**, 682, 1948.

X-ray diffraction measurements indicate that the internal stresses in a number of metals were by no means irregular, being related in magnitude and direction to the previously applied stress.

The view of G. B. Greenough that results might be explained by intergranular stresses in grains of the same crystallographic orientation only is rejected. The authors conclude that two types of internal stress may arise in a metal during plastic deformation (a) the irregular stresses of anisotropy and inhomogeneities of granular

texture and (b) the regular type of internal stress associated with the response of the metallic lattice to external stress. E.W.J.M. (see Abstr. 517).

1053. **The Influence of Internal Stress on the Structure of Electro-Deposits**
M. R. J. WYLLIE. *J. Chem. Phys.*, **16**, 52, 1948.

It is shown that the Author's data on the properties of Cr electro-deposited from a standard chromic acid electrolyte fit well the assumption that the preferred orientation is the result of a slipping process, analogous to cold-working, which occurs during deposition when internal contractile stress reaches a certain critical value. It is further shown that the type of orientation is in accord with theory, and it is stated that (111) orientation is to be expected generally for body-centred cubic metals electro-deposited in a state of contractile stress, while (110) or (100) is to be anticipated for face-centred cubic metals deposited with the same type of stress. The orientations of a number of electro-deposited metals are shown to be in agreement with this expectation. Certain anomalies in the stress and orientation results for Ag, Ni, and Al deposits have also been studied experimentally, and the results explained. In conclusion, the possible mechanism of internal stress formation in electro-deposits is examined. SCI. ABSTR.

1054. **Coefficients of Viscosity and Thermal Conduction in Dense Gases and Liquids.**

L. M. YANG. *Nature*, **161**, 523, 1948.

An attempt has been made to deduce the coefficients of viscosity and thermal conduction respectively using the kinetic theory of liquids formulated by Born and Green. The Author provides general expressions for the two coefficients based on thermal motion and attraction of the molecules. E.W.J.M.

BOOK REVIEWS.

SYMPOSIUM ON METALLURGY OF STEEL WELDING

British Welding Research Association, 29 Park Crescent, London, W1.. Price 10s.

The symposium on the results of modern metallurgical research on the arc-welding of steel, held in London in November, 1945, under the auspices of the British Welding Research Association, consisted of four sessions, the first two dealing with "Weld Metal," the third with "Hardened Zone Cracking and Viscosity of Welding Slags," and the fourth with "Current Research." The dozen or so papers presented are now available in book form, together with the introductory remarks of the various chairmen, and the discussions. The whole forms a useful basis for the further study of a subject which already has reached the stage when it is difficult to acquire, in a reasonable time, any comprehensive impression of the volume of research that was done in the years immediately preceding the recent war and in the course of it, under the stimulus of the immense shipbuilding programmes of Britain and the United States. Rather curiously, there does not appear to be any mention of the actual date and place of the symposium; neither is there even the customary date on the title page. It may be noted, too, that some of the micrographs lack an indication of their magnification; an omission of much more importance than the date.

ENGINEERING.

FLOW THROUGH STANDARD NOZZLES, ORIFICE PLATES AND VENTURI TUBES

By J. R. FINNIECOME, M.Eng., M.I.C.E., M.I.Mech.E.

Mechanical World Monograph No. 39. Emmott and Co., Ltd., Manchester and London

The measurement of fluid flow in terms of the differential pressure across an artificial constriction in a pipe of circular cross-section was the subject, during the years between the wars, of several elaborate experimental investigations, primarily aimed at standardizing designs of equipment for industrial use and establishing numerical coefficients appropriate to a wide range of service conditions. The detailed results of these researches, published in different languages, and the standards set up, especially in Germany and the United States, are obviously of great interest to civil and mechanical engineers, and Mr. Finniecome has made an intensive study of the whole subject in order to present concisely a comprehensive survey of the physical aspects of flow measurement for air, steam, gases and water, by means of nozzles, diaphragm orifices and Venturi meters. Starting with the fundamental formulae based on the hydrodynamic and thermodynamic theories, he derives general expressions for flow through the three types of meter and qualifies them by empirical discharge coefficients, values of the latter, according to different authorities, being instructively compared. The effects of adiabatic index on the pressure/discharge relationships for air and steam are next introduced, in which connection the Author's graphical presentations of kinematic viscosities are likely to prove especially helpful to engineers who use such data only occasionally. The Author's concern being primarily with standardized metering, he pays a good deal of attention to the critical Reynolds numbers above which flow factors remain sensibly constant, though he says nothing of the characteristic behaviour of flowmeters at very low Reynolds numbers.

The highly condensed style makes this book essentially one for technicians who

are already well-versed in the theory and practice of fluid-flow measurement and are mainly interested in comparing the latest and most advanced data and performance formulae for the three commonest types of differential-pressure meters. Newcomers to the subject will find the mathematical and graphical matter, which forms the greater part of the book, somewhat unnecessarily difficult to follow, not least because of a large number of typographical errors, many of which are not apparent without laborious checking of equations and scrutiny of tables and graphs. For the careful reader, however, these defects will not detract seriously from his appreciation of Mr. Finnicome's attempt to analyse a great volume of important research and to reduce the results to a common basis. ENGINEERING.

ABSTRACT OF THE LAST PAPER PRESENTED ON MARCH 17th, and
of the FIRST PAPER PRESENTED ON MARCH 18th, AT THE ANNUAL
MEETING OF THE INSTITUTE OF METALS (1948).

In "The Young's Modulus of some Aluminium Alloys," N. Dudzinsky, J. R. Murray, B. W. Mott and B. Chalmers, described their attainment of increases in Young's Modulus, E , in complex aluminium-base alloys. All the five elements investigated increased E , the effect decreasing in the order Mn, Be, Co, Ni, Si. The development of high strength alloys having high E -values appeared possible. In the appended "The Moduli of Aluminium Alloys in Tension and Compression," S. F. Grover, W. Munro and B. Chalmers indicated that within the limits of experimental error, the values found for E in tension were identical with those in compression.

Points raised in the discussion included a call for the active co-operation of industry, so that alloys would not just be taken as they came, but built up from their elements as indicated by the new concepts. Further, it was stated that addition of metals not forming intermetallic compounds with aluminium, seemed unlikely to secure significant improvements in the elastic moduli above those already achieved. Heats of formation of an intermetallic compound could serve as guide to their likely E for the purpose of selection, since, qualitatively speaking, a high heat of formation implied higher inter-atomic binding forces, and thus high E values.

In France up to 15% Beryllium in Be-Cu alloys was found to increase E to a value above that of steel.

Dr. A. Latin's paper on "Pressure and Creep Tests at Constant Hoop Stress on Lead and Alloy—'E' Pipes" related to the creep of pure and alloyed lead pipes under constant pressure; the Andrade Creep Equation being applied.

Professor Andrade, in the discussion stated that whether rupture resulted from flow depended upon whether the material hardened or not at the point where thinning took place. It was possible to blow glass, since the thinning portions cooled and consequently hardened. It would not be possible to "blow" lead at 250° C., since there was no hardening at this temperature.

It was stated that the extension at fracture as well as the second-stage creep-rate in lead alloys, increased inversely as the grain size. M.W.T.