

BRITISH RHEOLOGISTS' CLUB



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EDITOR'S LETTER.

This is the first issue of the B.R.C. Bulletin "under entirely new management"—and it starts off well by being over a month late! The delay has been unavoidable: Editorial time is limited and, simultaneously with the Bulletin, I have had the task of preparing the copy for the Proceedings of the (1949) Bristol Conference, which has involved a good deal more than mere "editing". However, to make amends, the present Bulletin is bigger (if not better) than usual and the setting up of the Conference papers is proceeding apace. The Publishers whisper that there is every hope that the book of the Bristol Conference will be on sale by the coming spring or early summer; but, in view of past experience, it is probably wise to say no more at this stage!

My new responsibilities have made me realize as never before the great amount of work done on behalf of the Club during the past nine years by my predecessor, Dr. G. W. Scott Blair. The Club owes him a tremendous debt of gratitude and I am glad to have the opportunity of recording it in the Bulletin which, thanks largely to his efforts and enthusiasm, has grown steadily from a duplicated circular to an abstracting journal already recognized in the scientific world and probably destined to reach much wider fields in the future.

I have taken the opportunity of bringing our method of citing references into line with the recommendations of the Abstracting Services Consultative Committee. The only change needed has been to put the year of publication immediately before the volume number instead of at the end. The new method will be at once apparent from our pages and should cause no inconvenience. For the sake of uniformity, the small change is well worth while.

The panel of Abstractors is now being revised and I shall be very glad to hear from any members, in England or further afield, able to assist in this important work. Apart from our good friends "Sci. Abstr." "B.C.R.A." and other "friendly bodies," the task of preparing abstracts falls on the shoulders of a few individuals, and, but for their devotion, there would be no Bulletin. Not all journals are covered and replacements are needed for abstractors who, for one reason or another, are unable to continue contributing. So may I please hear from you?

V. G. W. HARRISON.

CLUB NOTES.

Future Meetings.

Flow Anomalies in Biological Systems to be held jointly with the Society for Experimental Biology at Cambridge on the 13th and 14th April 1950. Details will be circulated later.

A Conference on *Lubrication*, with informal discussions and exhibits, will be held jointly with the Institute of Physics (Manchester and District Branch) at the University, Manchester, on the 29th and 30th June and 1st July 1950.

Summer Visit on the 22nd July. Details will be circulated later.

Annual Conference at Reading University, on 28th, 29th and 30th September 1950. Members are invited to suggest suitable subjects for discussion.

Clay Minerals Group of the Mineralogical Society.

The Fourth International Congress of Soil Science is to be held in Amsterdam on 24th July to 1st August 1950 with a post-Congress excursion (15 days) through Holland and Belgium. The programme includes a "Section of Clay Minerals" with the following subjects for discussion:

- (1) Structure of Clay Minerals
- (2) Genesis and Synthesis of Clay Minerals and their mutual Transformation
- (3) Interstratified Clay Minerals
- (4) Differential Thermal Analysis of Clay Minerals
- (5) Crystal Structure and Ion Exchange
- (6) Solvation of Clay Minerals in relation to Crystal Structure.

In addition to the "Section of Clay Minerals" the following subject occurs under the heading of "Section of Soil Chemistry":

- (2) Determination of Exchange Capacity and Exchangeable Ions. *a.* Clay Minerals in Soils. There is also to be a meeting of an informal group on the "Technology of Clay Minerals."

Particulars may be obtained from Dr. P. A. Rowaan, Secretary of the Organising Committee of the Fourth Congress of Soil Science, 3, van Hallstraat, Groningen, Netherlands.

New Members.

The following new members have been elected since March 1949:—

MR. E. R. BALLANTYNE	Building Research Station, Graham Road, Highett, Victoria, Australia. Interests: Caulking compounds, building materials, bentonite suspensions.
MR. JOHN J. BENBOW	86, Atwood Road, Didsbury, Manchester, 20. Interests: Printing thickeners, colloidal solutions, fundamental properties of fluids.
MR. GEORGE L. BESSEY	British Whiting Research Labs., 235, Ampthill Road, Bedford. Interests: Putties and mastics, flow of fine powders, effect of filler properties on flow of pastes and suspensions.
MR. G. H. CLARK	121A, King Street, Duckinfield, Cheshire. Interests: Pharmaceutical preparations, ointments, creams, perfumes.

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| PROF. R. M. DAVIES | Department of Physics, University College of Wales, Aberystwyth.
Interests : Internal friction of solids. |
| MR. E. G. ELLIS | c/o Vacuum Oil Co. Ltd., Central Laboratory, York Road, Wandsworth, London, S.W.18.
Interests : Lubricants and viscometry. |
| MR. GRAHAM A. GORDON | The Printing, Packaging and Allied Trades Research Association, Patra House, Randalls Road, Leatherhead, Surrey.
Interests : Paper and board. |
| MR. A. GRAHAM | 10, Greendale Road, Blaby, Leicester.
Interests : Metals, creep and tensile testing. |
| DR. K. W. HILLIER | 24, Abbey Road, Enfield, Middlesex.
Interests : High polymers, dynamic elastic measurement. |
| MR. P. HOWARD | Chestnut Lodge, 121, Hare Hills Lane, Leeds, 8.
Interests : Suspensions and rotation viscometry. |
| DR. JOHN KNAGGS | New Barn, Micheldever Station, Winchester, Hants.
Interests : Proteins, synthetic resins, cellulose and paper. |
| MR. K. A. LAMMIMAN | c/o Research Council of the British Whiting Federation, 245, Ampthill Road, Bedford.
Interests : Mastics, paints, general rheology. |
| MR. J. M. LICKLEY | Research Department, Metropolitan-Vickers Elec. Co. Ltd., Trafford Park, Manchester 17.
Interests : Plastic deformation of the work material in metal cutting, large strain and high strain rate phenomena. |
| MR. G. W. MACK | Building Research Station, Bucknall's Lane, Garston, Watford, Herts.
Interests : Lime, concrete, plaster, mastics and paints. |
| MR. C. R. MAYNARD | Wiggins Teape Group Research Organisation, Stoneywood Mill, Bucksburn, Aberdeenshire. |
| DR. ROBERT L. SMITH | 10, Broomville Avenue, Sale, Cheshire.
Interests : Aqueous dispersions of vulcanizing ingredients and fillers for rubber latex. |
| MR. EIGIL STRØMSØE | Sofienberggaten 61D ¹ , Oslo, Norway.
Interests : Plastic materials. |
| MR. P. WHITELEY | c/o Cellon Ltd., Kingston-on-Thames, Surrey.
Interests: Oils, paints, mastics, emulsions and suspensions. |
| MR. P. S. WILLIAMS | The Retreat, Rydens Avenue, Walton-on-Thames, Surrey.
Interests : Paint, concentric cylinder viscometers. |

News of Members.

Dr. D. W. Gillings has now left the British Iron and Steel Research Association to join the Science Department of the National Coal Board.

Fisher Electroviscometer.

Mr. D. C. Broome sends us a copy of "The Laboratory" (published by Fisher Scientific Company and Eimer & Amend, U.S.A.) in which appears a description of the Fisher Electroviscometer, which, it is claimed, "conveniently measures the viscosity of true Newtonian liquids in the range of 0 to 5000 centipoises; viscosity readings can be made directly in the absolute unit, centipoise, to within 1% of the true viscosity. An outstanding advance in viscosity instrumentation, the Fisher Electroviscometer is the first viscometer that is truly direct reading." The instrument is of concentric cylinder type and a novel feature is that the restoring torque is applied by means of an electric current circulating round a small coil placed in a magnetic field. "The restoring force is varied by turning a control knob on the front of the power supply. With this knob the operator controls the movement of the coil against the contacts, balances the torque of the bobbin with the restoring force, and measures the viscosity which is read directly from the meter." The instrument is thermostatically controlled.

The viscometer looks a neat piece of apparatus, but at \$525 it is not likely to find its way into this country at present. Any member interested may borrow our copy of "The Laboratory" on request.

British Journal of Applied Physics.

It is with the greatest pleasure that we publish notice of the new *British Journal of Applied Physics* which the Institute of Physics has just launched as a monthly publication. We have been trying, unsuccessfully, to think of a neat substitute for the old cliché about fulfilling a long-felt want: the new Journal has been badly needed by industrial physicists and is very welcome. It deals with applications of physics, especially in industry, and is really the second part of the *Journal of Scientific Instruments and of Physics in Industry* now expanded into a scientific magazine in its own right, while the *Journal of Scientific Instruments* reverts to its original purpose of describing scientific apparatus and equipment. The style of presentation and printing are therefore familiar and are well up to standard, though we confess we find the cover a little disappointing—but this is a small matter.

Rheologists will find several items of special interest to them in this first number. J. Moore describes some chemical and physical properties of rubber. W. Lethersich and H. Pelzer write on the measurement of the coefficient of internal friction of solid rods by a resonance method, while R. Harper, A. J. Kent and G. W. Scott Blair describe the application of multiple factor analysis to industrial test data. A. J. Kent provides an additional note on the interpretation of multiple factor analysis. Indeed, as V. G. W. Harrison and S. R. C. Poulter discuss the measurement of opacity and reflectivity for printing papers, the names of contributors have a distinctly familiar ring. Other articles are on "A Scientific Education" by Sir Phillip Morris, and "The Development and Deionization Time of Heavy-Current a.c. Arcs." by J. S. Forrest. Foreword, Notes and News, and New Books complete the number.

Older members of the B.R.C. will not readily forget the generous help which the Institute of Physics gave the Club in the first precarious years of its existence and we wish the *British Journal of Applied Physics* every success. If the standard of the first number is maintained, this will be assured.

RHEOLOGY ABSTRACTS

NOTE.—The initials following the Abstracts are those of the abstracting member except for the following abbreviations for abstracts reproduced 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, Packaging and Allied Trades Research Association.
SCI. ABSTR.	Science Abstracts.
B.S.A.	Building Science Abstracts.

1467. An experimental study of thixotropy in bentonite suspensions.

T. ALFREY AND C. W. RODEWALD. *J. Colloid Sci.* 1949, 4, 283.

By focussing attention on the initial rates of restoration, it is possible to determine the flow curve of a suspension at a given stage of gelation. This practically eliminates uncertainties arising from an alteration of the structure by the act of measurement. Bentonite suspensions are found to be essentially Newtonian immediately following thorough agitation. The gelation process introduces an apparent yield point, and also reduces the slope of the flow curve. The gelation process is reversible, in the sense that thorough agitation returns the system to a reproducible sol state, which subsequently undergoes reproducible gelation. Superimposed upon the mechanically reversible gelation process is a slower, mechanically irreversible process of consolidation, referred to here as ageing. At any stage in the ageing process, a mechanically reversible gelation phenomenon exists; but the gelation properties are different for gels of different age. The rate of ageing is dependent upon temperature. Traces of dioxane very markedly reduce the tendency toward gelation.

B.C.R.A. (abridged).

1468. Rheological methods in the milling and baking industries.

A. J. AMOS. *Analyst*, 1949, 74, 392.

Various empirical instruments for assessing the working qualities of flour doughs are illustrated and described, with typical curves. These include the Brabender Farinograph, the Mixograph, the Chopin Alveographe, the Brabender Extensograph and the absorption meter and extensometer recently devised by Halton.

V.G.W.H.

1469. The rheology of paper : III, Graphical analysis of stress/strain curves for paper.

O. ANDERSSON, B. IVARSSON, A. H. NISSAN, B. STEENBERG. *Paper Maker*, 1949, 118 (5), 335.

The stress-strain curves are analyzed in terms of a three-element model consisting of a Maxwell element in parallel with a spring. Some of the practical applications of the results are discussed.

V.G.W.H.

1470. An automatic recording apparatus for the study of flow and recovery in metals.

E. N. DA C. ANDRADE AND A. J. KENNEDY. *Proc. Phys. Soc. Lond. B*, 1949, **62** (11), 669.

An apparatus is described which records continuously on photographic paper the extension-against-time curve of a metal wire creeping under stress. The length and time scales are recorded on the paper at the same time as the extension, so that deformation of the paper during development and drying does not affect the accuracy of the record which allows an extension of up to 10 cm to be read to within 0.02 mm. The apparatus also automatically removes and restores, repeatedly if desired, the load at times which can be set before the start of the experiment.

AUTHORS.

1471. The mechanism of dilatancy.

E. N. DA C. ANDRADE AND J. W. FOX. *Proc. Phys. Soc. Lond. B*, 1949, **62**, 483.

The dilatancy in question is the change of overall volume produced by strain in an assembly of particles. This has been demonstrated in the case of a mixture of sand and water by a photo-electric method of measuring the wetness of the surface. The general phenomenon has been experimentally studied in detail with a two-dimensional hexagonal array of uniform cylinders, part of the free surface of which is loaded with a rigid piston. An alternate increase and decrease of overall volume as the piston descends has been demonstrated and the mechanism of slip by which it comes about has been established. The elastic stress distribution in the array before slipping takes place has been calculated and shown to be a determining factor. The effect of friction between the component units has been studied. Experiments have also been carried out on three-dimensional irregular arrays of carbon shot and of sand.

AUTHORS.

1472. A study of ripening of Cheshire cheese.

M. BARON. *Dairy Industries*, 1949, **14**, 705.

A number of rheological tests, including the use of a sphere indenter and various types of penetrometer, were repeatedly applied to 11 Cheshire cheese during ripening in the store. Comparisons are made with subjective judgments of quality given by experts and it is concluded that the mechanical tests are able to predict to a considerable extent the manner in which the cheese will ripen.

G.W.S.B.

1473. Rheological measurements and adhesion.

J. F. T. BLOTT AND W. B. BONNOR. *Nature*, 1949, **164**, 799.

The phenomenon described by Mardles (*Nature*, 1949, **164**, 324) that rheological measurements with non-Newtonian liquids are dependent on the material with which the viscometer is made, has been considered in relation to results on yield stresses in lubricating greases determined under conditions of tangential shear. There is evidence to show that at shearing stresses above a certain value, termed the "first yield value," the flow of grease takes place by slip on a thin film of oil at the grease-solid interface. Following the views of Hardy, the first yield stress is due to the development of a rigid structure in the slip film of oil under the influence of adsorption forces and its magnitude may be dependent on the chemical nature of the surfaces in contact. Adsorption forces may also affect the thickness of the slip film of oil.

E.W.J.M.

1474. Thixotropic gelation of hydrosols of Fe_2O_3 and the effects of surface-active substances.

A. F. BOGOYAVLENSKIĬ. *Kolloidnyi Zh.*, 1949, **11**, 369.

The stability of thixotropic gels of alcoholic and aqueous Fe_2O_3 -salt mixtures is studied. Triangular diagrams are used to indicate the regions of stability. A number of different alcohols are used.

G.W.S.B.

1475. Effect of hydrostatic pressure on plasticity and strength.

P. W. BRIDGMAN. *Research*, 1949, 2 (12), 550.

Tests on simple tension, compression, bending, punching and Brinell hardness have been made in a "pressurized laboratory" 3" long and $\frac{1}{2}$ " diameter at pressures up to 450,000 lb/sq in. The ductility of steels increases with and is a linear function of hydrostatic pressure. The strain required for fracture depends upon the past history of the specimen. Wires drawn under very high hydrostatic pressure may be expected to have increased tensile strength at atmospheric pressure and preliminary experiments at 180,000 lb/sq in. have shown that this is so. Great increases of ductility under pressure are also noted for copper, aluminium, phosphor bronze, beryllium, cast iron, sodium chloride and sapphire: on the other hand, quartz and glass remain brittle up to 450,000 lb/sq in. Although glass does not lose its brittleness, its tensile strength may be greatly increased by pressure. Similar results are noted with "carboly". Some materials which remain brittle under tension show measureable plasticity under simple compression. Hydrostatic pressure raises the elastic limit and Brinell hardness of steel to a comparatively small extent. Experiments on forcing a cylindrical flat-ended punch through steel again show a big increase in ductility under pressure. A simple apparatus for torsion experiments under pressures of up to 750,000 lb/sq in. is described. These results may have a bearing on geological problems. V.G.W.H.

1476. Viscometer for thick liquids.

N. A. DE BRUYNE. *British Plastics*, 1949, 21, (246), 590.

Construction and use of the Techne capillary viscometer are described.

C.C.M.

1477. Servo-controlled tensile strength tester.

G. S. BURR. *Electronics*, 1949, 22, 101.

The instrument permits several types of tests, including cycling tests, on plastics, textiles and rubber, and is designed to: (1) provide considerable versatility of control; (2) avoid obscuring the properties of the material under test through its own characteristics; and (3) to cover a wide range of load sensitivities. A bonded-wire type of strain gauge forms one arm of a Wheatstone bridge fed from a 390 c/s oscillator. Balancing networks and a calibrated attenuator provide 6 full-scale load sensitivities on the recorder chart which is driven from the moving crosshead of the instrument. The load cell, located at the middle of the top fixed crosshead, is attached to the top jaw. The other pulling jaw is attached to the moving crosshead below, which is driven by 2 vertical screws and an amplidyne-controlled positional servo-mechanism. The error in position is kept below 0.0005 in and correction takes place in less than 0.5 sec. Full-scale load sensitivities extend from 2 g to 11,000 kg and the max. deflection of the weighing element itself is 0.003 in. Several records of cycling and other tests are shown.

SCI. ABSTR.

1478. Viscosity of polyvinyl chloride solutions.

J. W. CLARKE, P. G. CROFT-WHITE AND P. J. GARNER. *Nature* 1949, 164, 450.

Although cyclohexanone is a better solvent for p.v.c. than methyl ethyl ketone, plottings of η_{sp}/C for dilute solutions show a greater slope with the worse solvent, contrary to the views of Frith (*Trans. Farad. Soc.*, 1945, 41, 19 & 92). Results obtained with binary mixtures of the solvents suggest: (a) different solvents solvate the polymer to different extents, thus affecting the viscosity of the solution; (b) cyclohexanone is bound to the polymer in preference to m.e.k.; and (c) when the polymer solvated with m.e.k. is brought into contact with cyclohexanone, the preference for cyclohexanone is not shown immediately but the solvent exchange occurs slowly. Hence solvent molecules are firmly bound and not trapped in the coils of the chains. E.W.J.M.

1479. A general approach to the problem of viscous deformations.

G. COLONNETTI. *Atti Accad. Naz. Lincei (R. C. Cl. Sci. Fis. Mat. Nat.)* 1948, 4, 515.
In Italian.

The treatment is analogous to that of plastic deformation. It is proved that any viscous deformation may always be considered as the resultant of a deformation which does not change the stresses and another which does not change shape and dimensions of the solid body.

SCI. ABSTR.

1480. Formularisation of stress-strain curves.

D. CROWDEN. *Metal Treatment*, 1949, 16, 25, 37, 121 & 130.

A method is shown of calculating the physical properties of certain metals, i.e., magnesium-base alloys, using a curve of hyperbola type to represent stress-strain relationships. By combining a hyperbola with a parabola or by using two parabolas, the whole stress-strain curve of a necking material from origin to point of fracture can be covered. Tables to facilitate calculations are included.

I.D.I.B. (abridged).

1481. The creep of glass at high temperatures.

C. CRUSSARD. *Sheet Metal Industr.*, 1948, 25, 2471.

A description is given of some creep tests on glass; Pyrex glass was used and testing was carried out in (1) the quenched state, and (2) when annealed and slowly cooled; tests were made at 420° and 500°C with loads varying from 150 to 1580 g/sq mm. The results show an instantaneous elongation followed by transient creep, after which the creep rate becomes constant. On loading, the instantaneous contraction is almost equal to the initial elongation and is followed by marked creep recovery, the deformation being almost reversible. Consideration of the variations in instantaneous length indicates that the instantaneous deformation is not purely elastic. Creep was found to be more rapid for the quenched state; the abnormal creep found in the annealed state is reversible. In the second stage of creep only does the glass behave like a viscous liquid.

B.C.R.A.

1482. Plastic deformation of glass during scratching.

J. F. H. CUSTERS. *Nature*, 1949, 164, 627.

Micrographs of scratches made on an ordinary microscope slide glass by a diamond are shown. At the end of the scratch there are curled turnings when the load on the diamond was from 20 to 38 g. The length of the longest turning is about 0.3 mm. and the length of the scratches is 0.7 mm.

E.W.J.M.

1483. A study of silica refractories by torsion methods.

S. S. DAS AND A. L. ROBERTS. *Trans. Brit. Ceram. Soc.*, 1949, 48, 215.

Torsion tests carried out on two types of commercial silica refractories up to 1620°C showed that pronounced changes occurred in the mechanical properties on heating.

B.C.R.A. (abridged).

1484. A generalised deformation law.

E. A. DAVIS. *J. Appl. Mech.* 1948, 15, 237.

The strain distribution variable $\nu' = \gamma_3 - \gamma_1/\gamma_2$ (where γ_1 , etc., are the principal shear strains) is assumed to be a function of the stress distribution variable $\mu = \tau_3 - \tau_1/\tau_2$, where τ_1 , etc., are the principal shear stresses. In addition, the octahedral shearing strain is assumed to be a different function of the octahedral shearing stress. With the assumption of incompressibility, the principal normal strains are expressed in terms of these two functions. Modifications are discussed for the case of finite strain and for strain composed of elastic and plastic parts.

SCI. ABSTR.

1485. **Investigations on the role of intermolecular forces in the mechanics of high-elastic deformations. I. Molecular mechanisms and the equations of the kinetics of high-elastic deformations.**

B. A. DOGADKIN, G. M. BARTENEV AND M. M. REZNIKOVSKIĬ. *Koll. Zhur.* 1949, **11**, 314.

Relaxation times for rubber at various temperatures are calculated from a somewhat modified Maxwell equation and their logs. are found to be linearly related to the square of the "non-equilibrium" part of the strain. G.W.S.B.

1486. **Stress-strain rate relations for anisotropic plastic flow.**

J. E. DORN. *J. Appl. Physics*, 1949, **20**, 15.

A simple theory for stress-strain analyses during plastic flow of anisotropic sheet metals is proposed for the work-hardening range. The effect of orientation on the yield strength in simple tension and biaxial tension was discussed for various types of symmetry. The theory appears to be approximately correct for mild steel plates that exhibit planar isotropy. B.C.R.A.

1487. **Pendulum viscometer.**

F. J. FONTEIN. *Chem. Weekbl.*, 1949, **45**, 861.

Viscometer for checking the consistency of suspensions used in the heavy medium process for coal of the Dutch State Mines. The developed type of viscometer can be used for measuring the consistency of all suspensions employed in float and sink processes. It is also possible to measure the viscosity of Newtonian liquids with the instrument, if the apparatus is calibrated. AUTHOR.

1488. **Measurement of viscosity of fluids at elevated pressures. I. Apparatus for pressure range up to 200 atmospheres and for temperatures up to 150°.**

W. FRITZ AND W. WEBER. *Angew. Chem. B*, 1948, **19**, 123. *In German.*

The principle of the viscometer is that of a Höppler instrument enclosed in a pressure vessel. Detailed descriptions of the pressure chamber, the viscometer proper, pressure-tight electric connections, the thermostat, pressure build-up system and temp. and time measurement are presented. Several sample determinations are described. SCI. ABSTR.

1489. **A theory for creep of ceramic bodies under constant load.**

P. GIBBS AND H. EYRING. *Canad. J. Res. B*, 1949, **27**, 374.

The plastic flow and elastic behaviour of ceramic materials is treated using a statistical mechanical relaxation theory. It is found necessary to treat creep as involving 2 and, in some cases, 3 relaxation mechanisms. The methods necessary for treating such non-Newtonian flow are developed here for creep for the first time. The results obtained are in accord with expectations on the basis of reports of others for flow at constant rate of loading and constant rate of strain for other materials. SCI. ABSTR.

1490. **A mathematical formulation of the general continuous deformation problem.**

A. GLEYZAL. *Quart. Appl. Math.*, 1949, **6**, 429.

Stress-strain relations for finite strain of a continuous medium are formulated in tensor notation referred to an embedded co-ordinate system. Generalized definitions of Young's modulus and Poisson's ratio for finite strain are derived.

SCI. ABSTR. (abridged).

1491. Small motions in non-ideal elastic bodies.

F. GRASSMANN. *Schweiz. Bauztg.* 1949, **67**, 55. *In German.*

A linear differential operator is defined and used to generalize Hooke's law. The equations of motion in vector form are derived for the medium and used to obtain a wave equation for longitudinal and transverse waves. The form of the operators is given for some ideal bodies.

SCI. ABSTR.

1492. Discontinuous flow phenomena in gelatine gels.

V. R. GRAY. *Nature*, 1949, **164**, 584.

Relaxation phenomena in gelatine gels were examined in a Couette type viscometer which was fitted for the measurement of optical birefringence; the extinction angle and double refraction in the gels were followed simultaneously with the mechanical relaxation of stress. The phenomenon of a discontinuous change in the flow properties was observed during the course of the relaxation. Typical curves are given; the first part of the curves was in accord with Schwedoff's equation, then suddenly the flow behaviour changed completely. It seems that an array of springs and dashpots can never represent the behaviour as the "constants" change with conditions.

E.W.J.M.

1493. Complementary minimum principles for an elastic-plastic material.

H. J. GREENBERG. *Quart. Appl. Math.*, 1949, **7**, 85.

The mechanical behaviour of a body of isotropic material obeying the stress-strain law of Prandtl and Reuss is investigated. Two minimum principles relating to the mixed boundary value problem where the velocities are given on part of the surface and the rates of change of the surface stresses on the rest are derived. These play an analogous part to that of the principles of Castigliano and of minimum potential energy in the theory of elasticity.

SCI. ABSTR.

1494. On fundamental methods of measuring and calculating hardness.

V. K. GRIGOROVICH. *Zavodskaya Lab.*, 1949, **15**, 457. *In Russian.*

A review of the Brinell, Rockwell, Vickers and Shore methods, with their drawbacks.

From I.D.I.B.

1495. Mixture law for viscosity of a solution.

L. GRUNBERG AND A. H. NISSAN. *Nature*, 1949, **164**, 799.

From a comparison of vapour pressures and viscosities of solutions the authors deduced the following equation: $-\log \eta_s = N_1 \log \eta_1 + N_2 \log \eta_2 + N_1 N_2 d$ where η_s is the viscosity of the solution, N_1 and η_1 are the mole fraction and the viscosity of component 1, N_2 and η_2 the mole fraction and viscosity of component 2, and d is the characteristic constant of the system. Closer agreement with experimental results was obtained in many cases than by using the equation of Arrhenius, namely $\log \eta_s = N_1 \log \eta_1 + N_2 \log \eta_2$.

E.W.J.M.

1496. Strain gauge for testing metal at high temperatures.

G. GUARNIERI AND J. MILLER. *Metal Progr.*, 1948, **54**, 692.

A strain measuring system is described for determining the elastic modulus, proportional limit, yield stress, and creep deformations of sheet metal at temperatures up to 1800°F. The device permits routine and accurate measurement of 0.0001 in. change in gauge length over a range of approx. 0.2 in. An extensometer system described utilizes 8 strain gauges, so mounted as to cancel out numerous variables and record a single equated value at any instant.

SCI. ABSTR.

1497. Further developments in the Vistex method for the determination of the intrinsic viscosity of high polymers.

D. A. HENDERSON AND N. R. LEGGE. *Canad. J. Res.*, 1949, **27B**, 666.

Baker's "Vistex" Intrinsic Viscosity is that obtained from a direct solution of latex in mixed hydrophobic and hydrophilic solvents. The log. of this quantity is shown, for butadiene-styrene mixtures, to be linearly related to the log. of the ordinary intrinsic viscosity in toluene. Other relations are also given. G.W.S.B.

1498. Measurement of high viscosities at low temperatures.

J. HENNENHÖFER AND W. FRITZ. *Angew. Chem.*, 1948, **20B**, 201. *In German.*

Standard types of viscometers for high viscosity measurements are described and their disadvantages noted. The new viscometer consists of a precision-bore tube (immersed in a special low-temp. thermostat). The oil under test is made to rise in the tube under 60 cm water pressure (obtained from compressed air) and the time required by the oil to rise between fixed marks is observed. Viscosity is proportional to the time taken. The flow velocity decreases along the tube (due to back-pressure of the oil column), and by affixing more than two marks and noting the time taken by the oil to rise between them additional information can be gained as to whether it is a normal or abnormal liquid. This makes the calculation of a mean value of viscosity possible in one single run. The low temp. thermostat used by the former Physikalisch-Technische Reichsanstalt is described. SCI. ABSTR.

1499. Notes on viscosity, plasticity and internal friction.

R. L'HERMITE. *Institut Technique du Bâtiment et des Travaux Publics, Annales*, 1948, No. 8, Paris.

A theoretical discussion with particular reference to plastic deformation in liquids and in metals. B.S.A.

1500. The vibration of fresh concrete.

R. L'HERMITE AND R. TOURNON. *Institut Technique du Bâtiment et des Travaux Publics, Annales*, 1948, No. 11, Paris.

Extensive theoretical and experimental researches. The authors study the relation between vibration characteristics and properties of the vibrated concrete such as internal friction, "viscosity" and "workability." An extensive bibliography on the vibration of concrete is appended. B.S.A. (abridged).

1501. A method of measuring some dynamic elastic constants and its application to the study of high polymers.

K. W. HILLIER. *Proc. Phys. Soc. Lond. B*, 1949, **62** (11), 701.

The preliminary work on the measurement of velocity of propagation and attenuation of longitudinal sound oscillations in high polymer filaments already described by Hillier and Kolsky has been continued. It was concluded in that paper that temperature control would be advantageous, and that by varying the temperature and the frequency of oscillations more useful information could be acquired. An apparatus is described whereby the velocity of propagation and the attenuation of longitudinal oscillations throughout the range 0° to 50°C and 500 c/s to 30 kc/s can be measured. The results obtained with one material, polythene, are discussed in terms of several theories of the elasticity of high polymers, and the constants of the several equations considered are calculated from the data. AUTHOR.

1502. The staling of bread.

H. M. R. HINTZER. *Chem. Weekbl.*, 1949, **45**, 797.

The characteristics of the staling of bread are considered; the tenderness is measured with a compression apparatus (panimeter), a description of which is given. The influence of substances, recommended as inhibitors, on the bread properties is described.

P.G.M.

1503. The determination of the hardness of organic films.

J. HOEKSTRA AND H. A. W. NIJVELD. *Rec. Trav. Chim. Pays-Bas*, 1948, **67**, 685. *In English*.

A special apparatus is described for measuring, with an accuracy of $\pm 0.1\mu$, the depth of penetration under load of a diamond point into a thin organic film, e.g. paint films. The diamond point is attached to a plate of a condenser and a differential effect is obtained by having fixed plates on both sides of the moving plate. This condenser forms two arms of a bridge and the measurement is performed during the application of the force. The results can be given in the form of "Vickers Hardness" figures. Results quoted for a lacquer show how the hardness varies with the thickness and, for a given thickness, with time. The instrument as described covers a range of Vickers Hardness of 0.5—100 kg/cm² whilst most lacquer films have a value of about 10 kg/cm².

SCI. ABSTR.

1504. The measurement of plasticity on ceramic bodies for pressing.

W. HUMMITZSCH AND A. G. BÖHLER. *Radex-Rdsch.*, 1949, **1**, 14.

Ceramic mixes are used for coating welding electrodes. The coating is applied either by dipping or, more recently, by pressing. For the pressing process plastic properties are required. In this connection the possibility of measuring the plasticity by means of the Brabender Plastograph is of particular importance. This permits a thorough study of the pressing properties of ceramic mixes.

B.C.R.A.

1505. Some aspects of the flow properties of glass of very high viscosity.

G. O. JONES. *J. Soc. Glass Tech.*, 1949, **33**, 65.

Experimental data on the flow properties of glass of very high viscosity, that is, at temps. below the transformation region, are reviewed and discussed from the standpoint of modern rheological theory. The form of the function governing the delayed elastic effect and the variation of the total magnitude of this effect with temperature are especially considered. Some of the contradictory statements existing in the literature on these points are discussed.

AUTHOR.

1506. The elastic modulus and the fatigue limit.

A. KAMMERER. *C. R. Acad. Sci. Paris*, 1948, **227**, 1144. *In French*.

The assumption of two coefficients of viscosity, together with a variation of elastic modulus with extent of strain, can explain both static and periodic mechanical properties, in tension and in bending, for such diverse materials as rubber, plastic materials and metals.

SCI. ABSTR.

1507. Rheological phenomena in the paint, varnish and printing ink industries : particular case of thixotropy.

F. KAUER. *1er Congres Tech. Internat. Ind. Peint., Paris*, 1947, 175.

A review of the main types of rheological systems and their characterization by torque/rate of shear graphs and relaxation curves obtained with the Couette apparatus.

P.A.T.R.A.

1508. A grain boundary model and the mechanism of viscous intercrystalline slip.

T. S. KÉ. *J. Appl. Physics*, 1949, **20**, 274.

A grain boundary model is described in which the transition region at the boundary is considered as consisting of numerous disordered groups of atoms or diffused holes. The intercrystalline slip occurs through the atomic rearrangement by thermal agitation within each "disordered group" by a shear process involving as units of flow only a few atoms. This grain boundary model and slip mechanism are consistent with experimental facts and furnish, furthermore, a unified viewpoint as to the mechanism of the viscous intercrystalline slip, the volume diffusion in metals, and the constant rate creep of metal crystals under small stress. Further experiments are described concerning the influence of previous deformation and impurities on grain boundary viscosity.

B.C.R.A. (abridged).

1509. Experimental verification of the fundamental law of plastic theory.

S. T. KISHKIN AND S. N. RATNER. *J. Tech. Phys., USSR*, 1949, **19**, 412. *In Russian*.

The Saint Venant and Huber-Mises theories were found not to be of general application and to be correct only in individual, special cases. The yield limit (under tangential stresses) cannot be regarded as a constant of the material and as independent of the method of loading. The relation between the true yield limits in tensile stressing and torsion depends on the structure of the material, i.e. on its lattice, the degree of metastability and homogeneity. The characteristic to be used for calculations should be the conditional yield limit determined from the formulae for elastic torsion, this being higher by 20-30% than the true yield limit in torsion. In calculating for torsion, the experimentally determined values of the conditional yield limits must be used instead of the old theoretical coefficients 0.5 and 0.6.

SCI. ABSTR.

1510. An investigation of the mechanical properties of materials at very high rates of loading.

H. KOLSKY. *Proc. Phys. Soc. Lond. B*, 1949, **62** (11), 676.

A method of determining the stress-strain relation of materials when stresses are applied for times of the order of 20 microseconds is described. The apparatus employed was a modification of the Hopkinson pressure bar, and detonators were used to produce large transient stresses. Thin specimens of rubbers, plastics and metals were investigated and the compressions produced were as high as 20% with the softer materials. It was found that whilst Perspex recovered almost as soon as the stress was removed, rubbers and polythene showed delayed recovery, and copper and lead showed irreversible flow. The phenomenon of delayed recovery is discussed in terms of the theory of mechanical relaxation and memory effects in the material.

AUTHOR.

1511. Mechanical properties of thixotropic systems undergoing brittle fracture.

N. G. KOLTASHEV. *Kolloidnyi Zh.*, 1949, **11**, 410.

An apparatus is described by means of which a plate immersed in the thixotropic gel contained in a cylindrical vessel is very slowly withdrawn by a cord passing over a wheel which turns at a constant speed. A number of different speeds (about 5 to 30 μ /sec) are available. A micro-scale attached to the cord is observed by means of a microscope and between the scale and the wheel there is a helical spring so that stress is gradually built up. Step-ladder shaped curves are obtained plotting time against scale reading (i.e. displacement of the plate).

G.W.S.B.

1512. Mechanical properties of solids. I. Elasticity of solids.

W. KÖSTER. *Fiat Rev. German Sci.* (1939-46) (Off. Mil. Govt. Germany) "Physics of Solids, I", 1947, 119. *In German.*

A method of measuring Young's modulus and impression hardness due to Kappler is described, in which crossed cylinders of the material are compressed and the elliptical contact area is examined until it has become circular. The formulae involve a knowledge of Poisson's ratio for the material. Oscillatory methods for measuring elastic constants of solids have been fully reviewed, and low temp. measurements of the elastic constants of single crystals of several metals have been recorded. The influence of temp. and other factors on the properties of alloys is discussed. SCI. ABSTR. (abridged).

1513. Dimensions and intrinsic viscosity of coiled chain molecules in solution.

E. D. KUNST. *Nature*, 1949, **164**, 535.

Using four fractions of polystyrene and four fractions of polyisobutylene, the molecular size R (root mean square distance between the ends of the coil) and the intrinsic viscosities (expressed in litre/g) were determined. By changing the solvent, R could be made to vary independently of the molecular weight: on passing from a good solvent to a bad one, the size of the molecule decreases considerably. The intrinsic viscosity is essentially a function of R only; molecules of different weight but of the same size have nearly the same intrinsic viscosity. E.W.J.M.

1514. A method of breaking emulsions.

A. S. C. LAWRENCE, D. BARBY AND O. S. MILLS. *Nature*, 1949, **164**, 536.

Emulsions formed during extraction and unbreakable by the usual methods were broken rapidly and completely by the addition of a wetting agent (Teepol and Turkey red oil) under the conditions described elsewhere for breaking emulsions of sea water in fuel oil (Lawrence, *J. Inst. Pet.*, 1948, **34**, 821). Wetting agents, being more surface active than emulsifying agents, displace them and the emulsion breaks. Moderate heating accelerates breaking. E.W.J.M.

1515. Coefficient of anomalous viscosity.

C. MACK. *J. Appl. Phys.*, 1949, **20**, 225.

The equation for this coefficient (see Abstract 1236) is modified using Batschinsky's (*Zeit. f. Physik. Chemie.*, 1913, **84**, 643) relation between the viscosity and the specific volume and those for strain-, stress- and time-hardening and thixotropy change correspondingly. Prandtl's equation relating shear stress and shear strain is derived from the von Mises-Hencky condition $WG = \text{constant}$, where W is the energy of change of shape and G is the rigidity modulus. SCI. ABSTR.

1516. Rheological measurements and adhesion.

E. W. J. MARDLES. *Nature*, 1949, **164**, 324.

The effect of the nature of the liquid-solid interface on rheological measurements is discussed with particular reference to non-Newtonian liquids. Experiments with polished penetrometers of the same shape and weight, but of different materials, showed that the time and depth of penetration into a lime-base grease depended on the nature of the penetrometer material. The amount of grease adhering to a strip penetrometer was found to depend on the nature of the surface. These results indicate that surface adhesion may account for the peculiar behaviour of non-Newtonian liquids. Sir William Hardy's work on the force required to cause instantaneous breakaway between optical flats separated by films of various liquids is summarized and found to support the adhesion theory. P.A.T.R.A.

1517. The use of rheological tests in the pharmaceutical and cosmetrical industries.

R. H. MARRIOTT. *Analyst*, 1949, **74**, 397.

The use of a rotating cup viscometer in securing uniformity of "body" of some pharmaceutical pastes and creams is described.
V.G.W.H.

1518. An interpretation of the oil absorption of pigments.

C. C. MILL AND W. H. BANKS. *J. Oil Col. Chem. Assoc.*, 1949, **32**, 599.

Determinations of the oil absorption of pigments are essentially measurements of the oil required to fill the spaces not occupied by the pigment particles. Various factors as the nature of the medium, the state of the pigment surface, moisture, etc., indirectly influence the measurements because of their effect on the consistency of the paste at the end point. Other theories are discussed in relation to these views.
C.C.M.

1519. Research into boundary lubrication.

I. MORGHEN. *Maschinenbau & Waermewirtschaft*, 1948, **3**, 57 & 75. *In German.*

Friction in hydrodynamic lubrication depends on viscosity of lubricant, tear strength of lubricant and bearing metal and on atmospheric pressure. Author has designed instrument for normal friction range, $f = 0.06$ to 0.12 , giving reproducible results with accuracy of 0.001 for friction coefficient, based on four-ball testing principle. Measures accurately qualities of lubricants under specified conditions and influence of friction factors: dry friction, ball uniformity, change of geometrical shape, film thickness, gas atmosphere, change in bearing surface, kind of lubricant, load, temperature, bearing metals, stick-slip motion.
I.D.I.B.

1520. The elastic properties of silica gels.

L. A. MUNRO, J. G. McNAB AND W. L. OTT. *Canad. J. Res.*, 1949, **27B**, 781.

Variations in Young's Modulus of silica gels, especially with changes in pH, are followed by compressing cylinders between parallel plates.
G.W.S.B.

1521. The general principles of rheology.

A. H. NISSAN. *Paper Mkr.*, 1949, **118** (4), 259.

It is only the analytical form of empirical and inductive methods used in rheology which are suitable for use on paper.
P.A.T.R.A.

1522. The physical structure of paint films—Rigidity.

PAINT RES. STATION. *J. Oil Col. Chem. Assoc.*, 1949, **32**, 499.

Effect of ageing and weathering on the rigidity of paint films of various thicknesses is described. Rigidity is determined by torsional oscillation of a strip of the paint film.
C.C.M.

1523. Bending of beams with creep.

E. P. POPOV. *J. Appl. Physics*, 1949, **20**, 251.

A method of calculating stresses and deflections for beams whose material creeps is presented. Complete tension creep test data at constant temperature are used to define creep characteristics of the material. Then, by using Bernoulli's hypothesis of plane sections and the technique developed earlier for interpretation of the relaxation of the relaxation creep tests, a method of beam analysis is shown. Stresses and deflections may be calculated for any desired time interval. This includes the time prior to the occurrence of the steady state creep. The latter aspect appears to have been ignored by others.
B.C.R.A.

1524. Mechanical properties of solids. III. Harness of solids.

T. PÖSCHL AND H. BÜCKLE. *FIAT Rev. German Sci.* (1939-46) (Off. Mil. Govt. Germany) "Physics of Solids, I", 1947, 144. In German.

This technically important subject still rests on a largely empirical basis. Comparative tests can be made by many methods but the precise properties being measured are not clear. The concept has been investigated both macroscopically and microscopically, and the Zeiss Hanemann micro-hardness tester (1941) enables extremely small surface areas to be examined, so that actual inhomogeneities of the surface may be measured, and a start made in the interpretation of the results in terms of the more recent ideas on the subject.

SCI. ABSTR.

1525. Interchemical rotational viscometer.

PRECISION SCIENTIFIC CO. *Chem. Engng News*, 1949, 27, (38), 2728.

The Precision Scientific Co. has redesigned the Interchemical Rotational Viscometer and placed all operating parts within one housing. It consists essentially of a rotating sample cup and a stationary bob immersed in it. When the cup is rotated, the viscous drag on the bob is imposed on a coiled spring which is twisted through an angle measured on a calibrated disc. The speed of cup rotation can be varied from 10 to 400 r.p.m. in steps of 10 r.p.m. The consistency curve is produced by changing the speeds over a series of steps from low to high and back again and noting the corresponding deflections of the graduated disc. Forty changes in speed are possible in three minutes.

P.A.T.R.A. (abridged).

1526. The Weissenberg effect in sweetened condensed milk.

M. REINER, G. W. SCOTT BLAIR AND H. B. HAWLEY. *J. Soc. Chem. Ind.*, 1949, 68, 327.

When a vertical rod is rotated in certain overaged samples of sweetened condensed milk, the milk climbs up the rod. When a disc is rotated near the bottom of the beaker containing the sample, the liquid is drawn radially towards the centre. It is suggested that these phenomena, commonly called "Weissenberg Effects", are caused, in the case of condensed milk, by an uncoiling of globular protein molecules as a result of denaturation. Samples showing Weissenberg effects are sometimes also thixotropic.

AUTHORS.

1527. On an aspect of the mechanism of the formation of cracks in Gruyère cheese.

M. REINER, G. W. SCOTT BLAIR AND G. MOCQUOT. *Le Lait*, 1949, 29, 351.

In French Gruyère cheese there are not only holes which should be spherical but often cracks also appear which lie at characteristic angles in different parts of the cheese. The stress systems responsible for these phenomena are discussed in relation to changes in humidity, pH, etc. during the ripening of the cheese.

G.W.S.B.

1528. Elasticity beyond the elastic limit.

M. REINER. *Amer. J. Math.*, 1948, 70, 433.

The author distinguishes between "deformation" and "strain", denoting by strain that part of a deformation which is recovered when all external forces are removed; however, his work applied equally to those cases when the so-defined strain and deformation are identical. On the assumption that there is a one-to-one relation between the stress tensor and the strain tensor it is shown that this relation can be expressed in the forms

$$T_r^s = (F_{01} I_e + F_{02} II_e + F_{03} III_e) \delta_r^s + F_1 e_r^s + F_2 e_{\alpha}^s e_r^{\alpha}$$

$$e_r^s = (\Phi_{01} I_T + \Phi_{02} II_T + \Phi_{03} III_T) \delta_r^s + \Phi_1 T_r^s + \Phi_2 T_{\alpha}^s T_r^{\alpha}$$

where I_e , II_e , III_e are invariants of the strain tensor, I_T , II_T , III_T are invariants of the

stress tensor, the F 's are functions of the strain invariants and the Φ 's are functions of the stress invariants. The above relations are independent of any particular measure of strain, and the author chooses the Hencky (or logarithmic) measure in expanding his theory. By considering certain special types of stress fields the F 's are given meanings as generalized moduli of elasticity and the Φ 's as generalized coeffs. of elasticity.

SCI. ABSTR.

1529. The viscosity of suspensions of spheres.

J. V. ROBINSON. *J. Phys. Colloid Chem.*, 1949, **53** (7), 1042.

A modification of the Einstein equation

$$\eta_{sp} = kV/(1 - S'V)$$

is suggested, where S' is the "relative sediment volume" i.e. the volume which a sediment will occupy whose particles themselves occupy unit volume. To check this relationship, suspensions of glass spheres in concentrations by weight of up to 72% in two motor oils, castor oil, polyethylene glycol, corn syrup and sucrose solution were measured in a Buchdahl rotational viscometer. When V/η_{sp} was plotted against V straight lines were obtained, confirming the form of the relationship. S' is found to be a constant depending primarily upon the suspended solid, but k depends upon the suspension medium. The proposed equation was also tested against the published observations of Vand, with satisfactory results. S' is closely related to the effective volume of the suspended particles, but the physical significance of k is conjectural. Full details of the method of preparing the suspensions and measuring the viscosities are given.

V.G.W.H.

1530. On the statistical theory of rubber-like elasticity.

T. SAKAI AND A. ISIHARA. *J. Phys. Soc. Japan*, 1948, **3**, 171. *In English*.

A mathematical treatment is given leading to the following expression for the modulus of elasticity of rubber-like substances at the beginning of elongation $E_0 = 3\rho RT\lambda_0^2/m$. The expression is derived by taking into account the statistical distribution of the lengths of the vectors representing the chains constituting the substance. Consideration of the average entropy in the stretched state leads to the stress value.

SCI. ABSTR.

1531. Industrial application of Rheology.

G. W. SCOTT BLAIR. *Analyst*, 1949, **74**, 387.

The author reviews the reasons why it may be important to measure the rheological properties of industrial materials. The limitations of classical "physical properties" and models built up from them, the theory of quasi-properties and the applications of factorial analysis to the interpretation of rheological tests are briefly discussed.

V.G.W.H.

1532. Gas bubbles in liquids.

R. SEELIGER. *Naturw.*, 1949, **36**, 41.

This is a balanced survey of the fascinating though unfashionable subject of the size and rate of growth of gas bubbles in liquids. The author considers the clinging of gas bubbles to surfaces, the generation of vapour bubbles and of electrolytically formed gas bubbles, the growth and rate of rising of isolated gas bubbles in liquids, and the formation of gas bubbles on the surface of porous plates.

R.S.

1533. Flow of visco-elastic dispersed systems in tubes as affected by variations in viscosity (mobility?) and critical shearing stresses.

P. K. SHCHIPANOV. *Koll. Zhur.*, 1949, **11**, 363.

1534. Viscosity of water in oil emulsions.

P. SHERMAN. *Research*, 1949, 2 (12), 587.

The applicability of the Guth-Simha modification of Einstein's equation to W/O emulsions is investigated. The Einstein factors obtained experimentally are near the theoretical 2.5, but values for the Guth-Simha factor show neither constancy nor agreement with the theoretical value of 14.1. V.G.W.H.

1535. New hardness scale.

G. S. SMITH. *Engineering*, 1949, 188, 235.

Recent work by M. M. Khrushchov (*Zavodskaya Lab.* 1949, 15, 213) has shown an interesting relationship between Mohs' and micro-hardness values obtained with a diamond pyramid (Vickers). Thus a modified Mohs' scale may be used on a quantitative basis. No standards (minerals or test plates) are required since hardness values of the new scale are based on experimental values of micro-hardness expressed in kg/sq mm. The article tabulates micro-hardness for the standard minerals of Mohs' scale. When plotted on log. log. scale against Mohs' values it was found that all values, except that for diamond, lay nearly on a straight line. It is assumed that Mohs' minerals now lose status as standards; new hardness values are not relative to those of a set of minerals that may differ somewhat with their origin. New values are absolute and nearer to accuracy within tenths of a unit instead of whole number units. I.D.I.B. (abridged).

1536. Behaviour of paper under stress and strain.

B. STEENBERG. *Pulp. Pap. Mag. Can.*, 1949, 50 (3), 207 and 220 (Convention issue).

By means of a series of new recording instruments the stress-strain behaviour of paper has been studied under widely different conditions. The rate of strain has been varied by a factor of more than 10^6 . In the most rapid experiments, the paper breaks within a millisecond. The slowest experiment requires several days. The behaviour of paper in rapid and slow straining processes is different and so are the changes brought about in the material by the straining processes. This is shown, for example, by comparison of stress-strain curves and paper strained twice, first slowly and then rapidly and *vice versa*. The ultimate tensile strength increases very markedly in the rapid experiments, but the relative increase is also a function of the fibre composition of the paper. Extensibility is not affected very much by the rate of straining. From the stress-strain curves several properties of the paper may be evaluated, e.g., the initial and ultimate modulus of elasticity and thixotropic changes brought about by repeated cycles of straining. The plastic properties of the material are given by tracing apparent viscosity curves. The practical value of such information for judging the properties of, for instance, flongs, is discussed. Special attention is given to stress-relaxation of paper under constant deformation. This property may be very different for different papers. Some papers strained rapidly (0.001 sec.) will, while held under constant strain, relax extremely slowly and never completely. Others, strained to the same extent, will dissipate the energy completely in as short a time as 0.01 sec. P.A.T.R.A. (abridged).

1537. The rheology of paper. I. The practical significance of paper rheology.

B. STEENBERG. *Paper Mkr.*, 1949, 118 (4), 258.

It is not fair to compare the wet and dry tensile strengths of paper merely by stating the tensile strength. Similarly, it may not always be correct to say that a paper is weaker in the cross-direction than in the machine-direction, merely because the tensile strength is lower. A considerably higher elongation in the cross-direction has also an important bearing on the strength properties, making the material tougher in this direction. It is necessary to study the behaviour of papers at different rates of strain in different directions of the sheet—and at different relative humidities. The object of stress-strain testing is to determine the behaviour of paper during use. P.A.T.R.A.

1538. The rigidity of paper.

B. STEENBERG. *Paperin Jaykkyydesta, Suom. Pap.-Ins. Yhd.-Esitelmä*, 1948, 8, 280.
In French.

It is necessary to take into account both the elastic and plastic properties of paper when measuring rigidity. A narrow strip of paper under stress tends to "flow" so that the rigidity cannot be determined by static experiments applying Hooke's law. The purely elastic rigidity may be determined by subjecting a strip of paper to vibrations perpendicular to its plane and of 50 cycle frequency. The length of the strip is varied until resonance occurs. The moduli of elasticity and rigidity can then be calculated from known formulae and since the oscillations are small, Hooke's law is obeyed. The apparatus may be used to calibrate Clarke's empirical tester (TAPPI Tentative Standard T451 m-44) in c.g.s. units. It is considered that the mechanical properties of paper are due not only to the orientation of the fibres, but also to the orientation of the molecules of cellulose on the surface of the fibres in contact.

P.A.T.R.A.

1539. Apparatus for testing springs in compression and tension on Rockwell apparatus.

N. M. STEPANOV-GREBENNIKOV. *Zavodskaya Lab.*, 1949, 15, 378. *In Russian.*

An improved test arrangement fitted to Rockwell hardness tester type RV made in Russia is described.

From I.D.I.B.

1540. Saint-Venant's and Filon's finite strains: definitions non-linear in displacement gradients.

K. H. SWAINGER. *Nature*, 1949, 164, 23.

A state of finite homogeneous strain is completely defined by the space derivatives of the displacement vector. Components of "true strain" can be defined in which terms involving products of the displacement gradients are absent. The case of three superposed pure strains parallel to Cartesian axes is discussed in detail. SCI. ABSTR.

1541. An anomaly in the classical theory on infinitesimal deformation.

K. H. SWAINGER. *Nature*, 1949, 164, 888.

It is shown that the general complex strain expressions of the classical theory on infinitesimal deformations which are of an unsymmetrical character cannot transform correctly with reorientation of co-ordinate axes.

V.G.W.H.

1542. On the general equations of problems of axial symmetry in the theory of plasticity.

P. S. SYMONDS. *Quart. Appl. Math.*, 1949, 6, 448.

The general equations for axial symmetrical problems are derived from the Mises flow condition and the Saint Venant-Levy-Mises stress-strain relations. These, with the equations of equilibrium, are investigated and, in general, form a system of elliptic type. Hence no real characteristic curves exist, except under special conditions where the problem reduces to one of plane strain.

SCI. ABSTR.

1543. Correlation of the Mohs's scale of hardness with the Vickers's hardness numbers.

E. W. TAYLOR. *Mineral. Mag.*, 1949, 28, 718.

This is a report on micro-hardness tests with a square base diamond pyramid of 136° angle on various substances known in the Mohs' scale. The quantitative diamond pyramid hardness values are in the same sequence as on the Mohs' scale and the author thinks it is now possible to correlate the two scales. He concludes that the question about the diamond pyramid hardness number for diamond remains unanswered. He believes

that impressions could be made on at least some faces of diamond, but in his experiments he has not cared to risk the loss of an expensive diamond point for this purpose.

I.D.I.B.

1544. On the mechanism of viscosity of liquids.

M. S. TELANG. *J. Chem. Phys.*, 1949, **17**, 536.

A new viscosity-temperature relationship for liquids has been derived, and its application has been studied. The derivation is based upon the theory of viscosity by Eyring *et al.*, rectifying the "activation energy" term. The "activation energy" term has been shown to be equivalent to the free energy of formation of a surface and the error committed by previous workers regarding the evaluation of "activation energy" has been discussed. The proposed equation is free from any arbitrary or empirical terms, and since, in particular, it does not involve any quantities derived from viscosity measurements, it makes a direct calculation of viscosity possible.

SCI. ABSTR.

1545. Interferometer study of slip bands on metal crystals.

S. TOLANSKY AND J. HOLDEN. *Nature*, 1949, **164**, 754.

1546. Interferometric examination of hardness indentations on tin.

S. TOLANSKY AND D. G. NICKOLS. *Nature*, 1949, **164**, 840.

The authors have shown by means of multiple-beam interference fringes that the Vickers pyramid indentation produces a distortion surrounding the indentation which is symmetrical on steel and asymmetrical on tin.

E.W.J.M.

1546. Changes in viscosity and conductivity during concentration of milk.

H. TORSSELL, U. SANDBERG AND L. E. THURESON. *Proc. 12th Internat. Dairy Congr. Stockholm*, 1949, **2**, 246.

Milk is studied during the process of drying by means of a Höppler viscometer. The viscosity-temp coeff. follows Walther's formula. The % total solids is given as $\frac{\log(T/b) - \log(\gamma - 0.8) - c}{d \log(T/b) - f}$

where γ = kinematic viscosity, T = absolute temp. and a, b, c, d, f are constants.

G.W.S.B.

1547. Faults in the consistency of butter and their characterization.

G. TVERDOKHLEB. *Molochnaya Prom.*, 1949, **10**, 24.

The consistencies of a number of butters from the Vologda region (USSR) are scored and compared with moisture contents, size of water globules, toughness, coherence and "quasi-viscosity" as determined by a penetrometer. A microscopic examination is also made.

G.W.S.B.

1548. Equations for the rheology of the Schwedoff Body.

N. V. TYABIN, *Kolloidnyi Zh.*, 1949, **11**, 438.

(Dedicated to the memory of Th. Schwedoff)

The author claims that Schwedoff, a Russian, should have the credit usually ascribed to Bingham as originator of formula for plastic behaviour. Tyabin's model for the Schwedoff Body differs from Reiner's in that it contains the sliding friction element in parallel with the Maxwell unit instead of in series.

G.W.S.B.

1549. The fundamental rheological equation for a Maxwellian fluid.

N. V. TYABIN. *Ž. Exp. Theor. Phys., USSR*, 1949, **19**, 559.

The equation of motion of an incompressible Maxwellian fluid moving in an external potential-force field is derived. It is shown that in steady one-dimensional flow a Maxwellian fluid behaves exactly as does a simple viscous fluid. Similarity conditions are considered: two flows are similar when the 4 dimensionless parameters $R_e = l_0 v_0 / \nu$; $F_r = \nu_0^2 / g l_0$; $H_0 = v_0 t_0 / l_0$; $S = \tau v_0 / l_0$ are equal for the 2 flows. In these parameters, l_0 is a representative length, v_0 the velocity of the stream, ν the kinematic viscosity, g gravitational acceleration, t_0 time, and τ the stress-relaxation period of the fluid.

SCI. ABSTR.

1550. Mortar and cement compositions.

F. G. UHLER. *Amer. Ceram. Soc. Abs.*, 1948, **48**, 9107.

Addition of water-soluble alkanolamines to lime plaster or Portland cement will improve their plastic properties, rate of set and hardness. B.S.A. (abridged).

1551. Use of cone indentation method for determining yield point with high speed deformation.

F. F. VITMAN AND N. A. SLATIN. *Zavodskaya Lab.*, 1949, **15**, 453. *In Russian.*

Continuing earlier work, authors develop theoretical equation relating radii ratio (indentation and surrounding "bruise" or swelling) with other relevant data, as follows $r^2/R^2 = (p - d)^2/R^2 = A^2 \Delta p$ where R is radius of base of swelling around indentation, r radius of indentation on flat initial surface of test piece, p radius of indentation on crest of swelling and d height of swelling, ($r = p - d$ for cone apical angle of 90°), e is deformation, and A and Δp are constants. Tests were made on mild steel to confirm validity of above equation in connection with cone indentation method for determining yield point with varying rates of deformation and isothermic temperatures. Velocity of cone indentation ranged from 10^{-6} to 10^2 m/sec. Some results are graphed showing the above formula is not valid for rates of deformation above 1 m/sec. evidently due to change of form of deformation with varying speeds. Effect of rate or force of impact on size and form of indentation and attendant swelling is further discussed and some results of tests at varying temperatures are graphed showing relation between yield point and deformation rate at these different temperatures. It is concluded that under proper conditions this method of determining yield point from extent and form of swelling around indentation can only strictly be recommended for low deformation or indentation rates, and in others can only be very approximate.

I.D.I.B.

1552. Visco-plastic flow of peat masses as affected by changing values of viscosity and critical shearing stress.

M. P. VOLAROVITCH AND P. K. SHCHIPANOV, *Kolloidnyi Zh.*, 1949, **11**, 384.

A study of peat masses in a tubular filter-press and of the effects of the compression along the tube on the rheology of the material.

G.W.S.B.

1553. Properties and application of hard polyvinylchloride.

H. T. VOORTHUIS. *De Ingenieur*, 1949, **61**, Mk. 121.

Properties of hard polyvinylchloride are described; the influence of the plasticiser content on the flow properties is studied with the Rossi-Peakes flow tester. P.G.M.

1554. Autographic method for measuring stiffness of non-rigid plastics.

R. D. DE WAARD. *Modern Plastics*, 1949, **27** (1), 115.

An apparatus is described in which the sample is supported on a cantilever and is strained at a uniform rate by a screw acting at its free end. The force induced by the straining is measured by strain gauges attached to the clamp support which is itself a

second cantilever. The measured strain is corrected for movement of the clamp to obtain true strain. The strain gauge output is recorded on a drum synchronised with the screw to give directly stress-strain curves from which the stiffness of the material is calculated. C.C.M.

1555. Measurement of viscosity of fluids at elevated pressures. II. Investigation of viscosities of oils at pressures up to 1000 atmospheres and temperatures up to 120°.

W. WEBER. *Angew. Chem. B*, 1948, **20**, 89. *In German*.

A falling-ball method was used to determine the effect of pressure on the viscosity of oils. 9 oils were investigated with an improved apparatus from 1 to 200 atmospheres and at 120°. 12 more oils were investigated in an older apparatus up to 1000 atmosphere and up to 60°. Paraffinic mineral oils show less pressure effect on viscosity than naphthenic oils when compared at equal viscosity. The pressure coeff. of viscosity can be correlated with the viscosity pole height of Ubbelohde in a manner satisfactory for technical purposes. The experimental details and evaluation of results are presented and considerable data are given. SCI. ABSTR.

1556. German viscometry—new apparatus for very heavy liquids.

H. WILLENBERG AND W. FRITZ. *Angew. Chem. B*, 1948, **20**, 134. *In German*.

Investigation of viscosity and flow of very viscous liquids or plastic masses—liquids not conforming to Newtonian laws—requires instruments which can be used with high flow resistances, and which permit study of flow and shear stress with repeated tests of the same sample. Such an instrument was designed by the German Office of Weights and Measures, Thuringia. It consists mainly of two cylinders connected by a capillary, and two loaded pistons, the liquid being forced by one piston to the second cylinder through the capillary and then back again by the second piston. The instrument is described in detail and formulae for series of curves worked out. SCI. ABSTR.

1557. Application of rheological methods to the paint industry.

P. S. WILLIAMS. *Analyst*, 1949, **74**, 400.

The rheological requirements of paints intended for brushing, dipping and spraying are stated. The use of efflux viscometers, Gardner mobilometer, Brookfield viscometer and B.S.I. U-tube and falling sphere methods as control methods for the paint industry are outlined. Reference is made to the work of Green & Weltman on thixotropy, the band viscometer of Wacholtz & Asbeck, and alternating stress techniques for determining rigidity and dynamic viscosity. V.G.W.H.

1558. Structural-mechanical properties of coagula. III. Deformations under shear of coagula of As and Sb sulphides.

B. G. ZAPROMETOV. *Koll. Zhur.*, 1949, **11**, 328.

1559. Viscosities to 30,000 kg/cm². Further rough compressions to 40,000 kg/cm².

P. W. BRIDGMAN. *Proc. Amer. Acad. Arts Sci.*, 1949, **77**, 117.

The viscosities over a millionfold range were determined by rate of movement of a swinging vane making and breaking an electric contact. The viscosity increased approximately exponentially with pressure: usually the plot of $\log \eta$ against pressure was at low pressures concave toward the pressure axis, but at higher pressures the curvature reverses. Higher pressures usually induce freezing, but methyl (2.2), n-propyl (4.5), iso-propyl (7) and n-amyl alcohol (6.2), and n-butyl bromide (5.1) were measured over the full range.

(The figures in brackets are the $\log_{10}$ relative viscosity at 30,000 kg/cm².) The viscosity of the lower members of dimethyl siloxane polymers increased with abnormal rapidity with pressure. The extension of pressures to 40,000 kg/cm² was made possible by sealing the liquid inside a thin lead capsule and the overall compression of the capsule with its contained liquid was determined: pressure was applied by advance of a $\frac{1}{2}$ " diameter piston. The results for numerous hydrocarbons, chlor-hydrocarbons, esters and other liquids are given in table form. E.W.J.M.

1560. The theory of plane plastic strain for anisotropic metals.

R. HILL. *Proc. Roy. Soc. A*, 1949, **198**, 428.

A yield criterion and plastic stress-strain relations are formulated for anisotropic metals deformed under conditions of plane strain. The equations are shown to be hyperbolic, the characteristics coinciding with the directions of max. shear strain rate. When the anisotropy is uniformly distributed, the variation of the stresses along the characteristics is expressed in terms of elliptic functions, and geometrical properties of the field of characteristics are established. The theory is applied to the problem of indentation by a flat die. AUTHOR.

1561. The effect of instantaneous pre-strain on the character of creep in lead polycrystals.

A. J. KENNEDY. *Proc. Phys. Soc. Lond. B*, 1949, **62**, 501.

The extension-against-time curves of Pb wires that have been subjected to rapid strain just before the experiment may be expressed by the Andrade creep equation $1 = 1_0(1 + \beta t^{\frac{1}{3}}) \exp(\kappa t)$ using the same constants as those which satisfy the creep of the metal under the same constant stress, but with the t value associated with β replaced by $(t + t_0)$ where t_0 is a constant for a given experiment, its value increasing with increasing pre-strain. While for pre-strains less than 10% the value of κ is unchanged by the pre-strain, for greater pre-strains the κ -flow is also modified and appears to approach more nearly to a linear variation with stress. AUTHOR.

BOOK REVIEWS

NOTE:—Our attention has been drawn to the fact that the price of Dr. Merrington's book "Viscometry" reviewed in Bulletin No. 23 is sixteen shillings and not six shillings as stated. We apologize for any inconvenience caused.

INDUSTRIAL RHEOLOGY AND RHEOLOGICAL STRUCTURES.

By H. GREEN. John Wiley & Sons, Inc., New York; Chapman & Hall, Ltd., London, 1949. pp. 311, xii. \$5.50. 33/-.

The scope of this book is defined by the author. It is intended for use in a control laboratory, and consequently the subjects considered and the treatment are of little use to the research laboratory. The book is divided into four parts. Part 1 is mainly a simple exposition of the author's method of analyzing the consistency curve obtained with a rotation viscometer and has been amply covered by his papers over the past ten years. A single chapter is devoted to the various other equations suggested for non-Newtonian systems. Part 2 is a description of experimental technique including the construction and use of the rotation and parallel plate viscometers, and a chapter on some control instruments which are widely used. Parts 3 and 4 are concerned mainly with the use of the microscope as an auxiliary instrument to the viscometer in elucidating the structure of pigment suspensions.

The book is simply and easily written and should be readily understood by the beginner for whom the author caters. There are two misprints in the text, one in connexion with Goodeve's theory on page 90 and the other in the derivation of the kinetic energy correction in a capillary tube on page 258. C. C. MILL.

(There is an amusing appendix on the status of prophets in their own country.—Ed.)

DEFORMATION AND FLOW: AN ELEMENTARY INTRODUCTION TO THEORETICAL RHEOLOGY.

By MARKUS REINER. H. K. Lewis & Co. Ltd., London, 1949. pp. 346, xix. 32/6.

This book, we are told, has been composed around "another bunch of leaves" taken out of the manuscript of the author's large unpublished text book on rheology finished in 1939. It therefore supplements the well-known "Ten" (shortly to become Twelve) "Lectures on Theoretical Rheology" and in many ways forms an admirable introduction to them. It is more elementary and less mathematical than the "Lectures," requiring, in fact, nothing more than a knowledge of ordinary calculus, and it treats mainly of subjects not covered in the earlier book. The subject matter may be summarized by the chapter headings: deformation and flow; viscosity; plasticity; structural viscosity; rheological analysis of a rubber solution (with full numerical data and graphs); variable viscosity and power functions; the "generalized Newtonian liquid"; wall effects; volume elasticity and viscosity. Chapter 10 analyzes simple tension and extension, and the following chapter discusses work hardening. The mathematics of bending and torsion are given in Chapter 12; most of this chapter can be found in standard textbooks on strength of materials, but the rheologist, who is frequently not an engineer, will probably find it useful to have this material close at hand. The concluding chapters deal with creep; elastico-viscosity and firmo-viscosity; complex bodies; strength; dilatancy and the Weissenberg effect; postscript.

The outstanding features of the book are the clarity of treatment and soundness of the mathematics and physics. The author seems to stand by one's side explaining all difficult points and warning of the numerous mistakes that assuredly would be made without such assistance; and the book forms the best substitute for a course of personal tuition in rheology that the reviewer has yet found. The student who masters its contents will have a thoroughly sound foundation on which to base his further studies. A novel feature is the author's demonstration of several flaws in the reasoning (to say nothing of

downright mistakes) made by acknowledged masters; to the student these errors can often be more instructive than the correct solution to the problem. Another useful addition is the "summary" given at the end of each chapter. The author's outlook is that of a mathematician and classical physicist—thus "dashpots and springs" are much more prominent in his later pages than power laws and quasi-properties. Nevertheless, he shows himself to be not unsympathetic to the integrative and psychophysical schools, wisely recommending that they should be studied at their source rather than in a second-hand version. Errors and misprints are few; the printing and binding of the volume leave nothing to be desired; and the price is reasonable by present standards. "Deformation and Flow" may be confidently recommended.

V. G. W. HARRISON.

A SURVEY OF GENERAL AND APPLIED RHEOLOGY (2ND ED.).

By G. W. SCOTT BLAIR. Sir Isaac Pitman & Sons, Ltd., London, 1949. pp. 314, xv. 40/-.

This is an old friend revised, enlarged and—one would like to say, brought up to date, but, in fact, only brought up to about the middle of 1947. The book follows the first edition in general plan, but large sections are either new or completely rewritten. There is a tantalizingly brief "Historical and General Introduction," followed by Part 1 on "Rheological Phenomena and their Measurement" and Part 2 on "Rheological Interpretations and the Evidence of Psycho-physical Investigations." The last 60 pages are devoted to summaries of rheological papers, a bibliography of some 1300 references, and indexes. The book forms an interesting contrast and complement to Reiner's "Deformation and Flow." One leaves Reiner satisfied that rheology is a nice, orderly subject befitting the noble intellect of man: Scott Blair flings us rudely back among the two-and-seventy jarring sects and we close his pages in despondency admitting that we are, after all, still but little children in the dark. Reiner's outlook is (mainly) conservative, physical, analytical: Scott Blair's is (mainly) revolutionary, psycho-physical, integralist. Both are necessary to get a balanced view of the subject, and it would be hard to find a more suitable pair of books with which to start a rheological library. The first part of the "Survey" is virtually a source-book—and a valuable one withal. The author has read and indexed the literature with a thoroughness equalled only by the compilers of German grammars and it would almost be a relief to find that something had escaped his net. It is therefore all the more deplorable that publication (through no fault of his own) should have been held up for the rheologically-considerable period of two years and that the volume should finally make its belated appearance at a price that will place it beyond the reach of many rheologists.

The second part of the book deals with interpretations, power laws and psycho-physics; and the author's views on these subjects are now so well known that they call for neither advertisement nor explanation. Whether one agrees with them or not, they cannot wisely be ignored. A few points occur to the reviewer. The five "Bhútas" of Hindu rheology mentioned on page 6 are obviously closely related to the ancient "elements" of earth, water, air, fire and "ether." These were never thought of as elements in the modern sense, but rather as Modes of Being, and the idea is developed at considerable length in the literature of modern Theosophy. It would be interesting to have more information about Indian rheology; perhaps the author will persuade an Indian student to oblige? Secondly, in his discussion on time scales on pages 236-238, the author could amplify his remarks by reference to the fact, well known to psychologists, that in the dream or trance state one can live through long and varied adventures all in a few seconds of Newtonian time. The reviewer is occasionally aware of, and can give some degree of attention to, two independent and interpenetrating space-time manifolds bearing no relation to each other. Here the non-Newtonian spatio-temporal nature of some subconscious mental processes is attested by direct experience. Finally, it is surprising to read on page 61 of this excellent book that "workability" in the case of mortar "is best defined in terms of the number of bricks which a given bricklayer can lay in a given time." Some of us thought that this number was determined by the *fiat* of the Trades Unions!

V. G. W. HARRISON.

PLASTIC DEFORMATION

By L. N. KACHANOW, N. M. BELIAEV, A. A. ILYUSHIN, W. MOSTOW AND A. N. GLEYZAL.
Mapleton House, New York, 1948. pp. 192. \$8.

This book is a compilation of work on the mathematical theory of plasticity developed during the war years in Russia, translated for the United States Navy Department by the applied mathematics group of Brown University.

It is in the form of seven distinct but allied chapters by five authors. The first chapter on "The Mechanics of Plastic Solids" by Kachanow starts with the general determinants for the stress and strain tensors for an isotropic solid and derives Hencky's equations for the strain in the three principal dimensions involving the modulus of plasticity; the conditions are postulated for the existence of a "work of deformation" function. Bodies whose behaviour under load is represented by equations involving this function are characterized by their comparative hardness, and in these it is assumed that the increase in internal energy is equal to the work of deformation. Using the principle of virtual displacements, the equations are derived for the resultant displacement in terms of the work involved for (1) an elastic body, (2) a perfectly plastic body and (3) a plastic body that exhibits strain-hardening. The second chapter, by N. M. Beliaev, discusses and elaborates the known theories of plastic deformation—principally those of Saint Venant, Mises, Hencky and Reuss, and establishes their inter-relations. The solutions to several problems involving tension and torsion of cylinders are given.

Chapters 3 and 4, by A. A. Ilyushin, deal with the fundamental laws of mechanics for elastic and plastic deformations and derive the relationship between the theory of Saint Venant-Levy-Mises; the theory of small elastic-plastic deformations and the conditions under which it is confirmed by experiment are also examined. Two theories are of interest which clarify the relation between the above theories: the first asserts that the theory of plastic deformation is a special case of that of plastic flow, and the second proves that this theory is a logical consequence of the theory of plastic flow under practical conditions.

Chapter 5, also by Ilyushin, gives in detail the theory for small plastic deformations; chapters 6 and 7, by W. Mostow and A. N. Gleyzal respectively, deal experimentally with the plastic deformation of thin plates under hydrostatic pressure.

The material collected in this monograph would certainly seem to have justified its translation into English. The frequent editorial footnotes are commendable and save the reader's time in following the sometimes obscure reasoning of the original authors. The only criticisms that could be levelled against the book as a whole are, first, that the mathematical equations have been written in longhand and are not easily legible; secondly, that page 17 appears to be a word-for-word copy of page 16 with the first line and function in the second chapter left out; and thirdly, the misplacement of Figs. 2 and 3

E. B. COLEGRAVE.

(From B.C.R.A.)