

Reserve

THE
BRITISH SOCIETY
OF RHEOLOGY

2107

2123

2126

2133

2135

2139

2141

2142

2143

2152

2161

HISTORY
NOT TO BE REMOVED
FROM
FILE.

(1951-52)

President :

MR. A. G. WARD

Past-Presidents :

SIR GEOFFREY TAYLOR, F.R.S. (1940-42).

SIR CHARLES GOODEVE, F.R.S. (1942-44).

PROFESSOR E. N. da C. ANDRADE, F.R.S. (1944-47).

PROFESSOR J. B. SPEAKMAN (1947-48).

PROFESSOR N. F. MOTT, F.R.S. (1948-49).

DR. G. W. SCOTT BLAIR (1949-51).

Committee :

Honorary Treasurer :

DR. J. G. OLDROYD,

Messrs. Courtaulds Ltd. Research Laboratory.

Honorary Secretary :

MR. P. FELTHAM,

The British Iron and Steel Research Association,
140, Battersea Park Road, S.W.11.

Honorary Editor :

DR. V. G. W. HARRISON,

Lyndhurst, Links Way, Little Bookham, Surrey.

DR. L. GRÜNBERG,

Mechanical Engineering Research Organization, D.S.I.R.

DR. E. W. J. MARDLES,

Royal Aircraft Establishment.

DR. B. SUSAN NEUMANN,

The Fullers' Earth Union, Ltd.

PROFESSOR A. W. SKEMPTON,

Imperial College of Science and Technology.

MR. W. A. RICHARDSON,

British Cotton Industry Research Association
(co-opted as North of England representative).

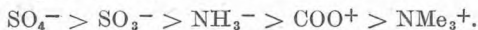
Honorary Auditor :

MR. A. de WAELE,

Messrs. Gestetner, Ltd.

RHEOLOGY OF FILMS AND SURFACES

THE annual conference of the British Society of Rheology was held jointly with the local section of the Chemical Society at the Washington Singer Laboratories of the University College of the South-West of England, Exeter, during September 27-29. The conference was opened by Prof. H. T. S. Britton and by Dr. G. W. Scott Blair, president of the Society. On the afternoon of September 28 a visit was arranged to St. Mary's Abbey, Buckfast, when Brother Adam demonstrated the thixotropic breakdown and other rheological properties of honey in production processes. Papers were read by B. A. Pethica and by J. H. Schulman and M. Z. Dogan (Department of Colloid Science, Cambridge) dealing with the properties of insoluble monolayers at an air/water interface in the presence of some soluble long-chain electrolytes of strong activity. Comparison of the Langmuir isotherms for penetration of liquid-condensed chloesterol with a series of straight-chain C_{12} compounds has shown that the polar head group specificity falls off in the order :



In the case of the interaction of saponin with condensed chloesterol, where a stoichiometric complex is formed, the penetration isotherm shows a transition corresponding to the formation of a two-dimensional solid film. The areas of the saponin show a corresponding change in the transition zone.

Studies have also been made of the penetration of myristic acid by dodecylamine hydrochloride and of the properties of protein films in the presence of electrolytes in relation to the tanning industry. Prof. F. H. Garner and Dr. C. W. Nutt (Department of Chemical Engineering, Birmingham) read a paper on cybotactic phenomena at interfaces, describing experiments on the movement of droplets in viscous media. Evidence on the molecular orientation into a quasi-crystalline structure was discussed in its relation to chemical engineering phenomena, for example, mass transfer across interfaces.

E. Eisma (Netherlands) described experiments on the rheological properties of interfacial films on water. For films of high yield-stress and small viscosity the rotating disk method is suitable, while in the case of purely viscous interfaces the torsion oscillation method has an advantage.

Under the chairmanship of Prof. M. Reiner (Haifa), K. V. Shooter (Research Laboratory for the Physics and Chemistry of Surfaces, Cambridge) described the mechanism of boundary lubrication at light loads taking into account the pressure-dependence of viscosity of oil films. H. J. Bezer and Dr. R. Schnurman (Manchester Oil Refinery) discussed experiments with extreme-pressure lubricants using a four-ball apparatus of the Boerlage type. There was no evidence for a defined 'breakdown load' of a lubricant. An energy balance would appear to allow for an appreciable proportion, up to 10 per cent, of the mechanical energy to be available for the separation of electrostatic charges.

At another session, with Dr. R. N. Saal (Netherlands) in the chair, C. C. Mill (Printing and Allied Trades Research Association) spoke on the rheology of printing, mainly of letterpress and lithographic processes, the photogravure process being fundamentally different and generally simpler rheologically. There was a discussion on the significance of the phenomenon of parallel ridge formation in the ink film on rotating rollers in contact. M. R. Hopkins (British Iron and Steel Research Association) spoke on the mechanics of the coating of steel sheet with molten tin between rollers. A mathematical investigation based on arguments similar to those used in the theory of lubrication gives a relation between the coating thickness and the relevant variables for a single pair of rollers. This relation was found to be in accord with experimental results obtained with a sheet of nickel foil emerging from a bath of oil through a pair of polished stainless-steel rollers under precise conditions of test. A. de Wael and G. L. Lewis (Gestetner) read a paper on the electrical behaviour of oil-pigment dispersions. They have found that a dispersion with electrically conducting particles behaves differently according to the state of flocculation, whereas with non-conducting particles there is little difference. Conductive systems do not seem to obey Ohm's law. It is possible to correlate the electrical with the rheological behaviour. Materials exhibiting dilatancy—for example, titanium oxide in liquid paraffin—increase in conductivity during shear and rapidly decrease to a constant value on arrest of shear. In strong deflocculating media, such as carbon black in polymerized linseed oil, the dispersions with high yield values show neither conductivity nor high dielectric constant.

D. W. Jopling (Kodak, Ltd.) described apparatus with a servo-mechanism, designed to measure the rate of radial flow of a liquid between parallel surfaces, for the purpose of ascertaining the rate of swelling of colloidal films. The swelling of a film on one of the

parallel surfaces alters the rate of flow between the plates, making it possible to calculate the increased thickness. E. Bielak and Dr. E. W. J. Mardles (Royal Aircraft Establishment), in a paper on the flow of liquid films over solids, reported that from experiments on the flow of drops along inclined planes and through capillaries, and on the radial spread of liquid pools over and between surfaces, anomalous flow-rates have been found. The flow behaviour over any one surface varies considerably with the chemical character of the liquid. Between surfaces, with films of thickness less than $10\ \mu$, there is a tendency for the film to disrupt with the formation of pin holes and with a consequent onset of film plasticity and thixotropy, noted by earlier investigators with lubricants. This phenomenon appears to be significant in relation to the 'wringing' together of flats, hydraulic 'stiction' and the development of rigidity in lubricant films. E. W. J. MARDLES

Bulletin No. 32

September, 1951

Price to non-members, 5s.

EDITORIAL

Dr. Scott Blair's letter reproduced in this issue makes depressing reading. It is probably wise to refrain from comment until there has been a meeting of the Joint Committee, but collapse of the plans for an international abstracting bulletin raises the problem of our own Bulletin's future. So far, we have striven to maintain its size and scope so that expansion to an international bulletin could be made as smoothly as possible. A recent further increase in the cost of printing coupled with an increase in the number of abstracts available for publication has now made cuts inevitable, and the problem is to effect substantial economies in publication costs without impairing appreciably the usefulness of the Bulletin.

Committee gave much thought to this problem at a meeting on October 4. Since it appears that we have to continue indefinitely with "an independent editorial policy", we have either to increase revenue or to decrease the size of the Bulletin. Prospects of our getting more money for publishing are far from encouraging, and it appears that the only practicable course is to reduce to about one half the space devoted to abstracts. This is now being done, starting with the present issue. Notes on original experimental work, if received, will continue to be printed as before.

As far as possible we shall continue to draw readers' attention to all papers of rheological interest published; but about half of these will be cited by title only. These papers will be from readily accessible journals such as *British Journal of Applied Physics*, *Journal of Applied Physics*, *Proceedings of the Physical Society*—journals which normally contain so many rheological papers that no rheologist who is doing his work properly can afford not to read them regularly. Of the remaining papers, about one quarter will be abstracted very briefly if the title is not enough to give an indication of the contents. The remainder, comprising mainly papers from trade journals and not-readily-accessible foreign periodicals will continue to be abstracted in full as before.

This present number of the Bulletin is frankly experimental. Further reductions and alterations may be necessary. Suggestions for the improvement of the Bulletin within the limited means at our disposal will be welcomed. We are sorry that any reduction in the Bulletin should prove necessary, but the news given in Dr. Scott Blair's letter leaves us no option in the matter.

V. G. W. HARRISON.

REPRINTS

There are available, gratis to those who apply, some reprints of papers from the *Journal of Colloid Science* by E. Richardson, E. Mardles and A. de Waele given at the Emulsions symposium, 1949. Application should be made to Dr. E. W. J. Mardles, Royal Aircraft Establishment, South Farnborough, Hants.

CORRESPONDENCE

Dear Harrison,

Exeter, 29 September 1951

When we last met, we agreed that, although the international situation with respect to Rheology would almost certainly be discussed at the Exeter Conference, I should write a letter for the Bulletin giving what information I can for the benefit of those members who, like yourself, are unfortunately unable to be at Exeter.

I think that most members know that just over two years ago, the International

Joint Committee (I.C.S.U.) decided that it would not be possible to finance even the very modest programme of work then felt to be needed under the restrictions imposed on "joint committees". An International Union of Rheology was therefore started which, together with a number of other small specialized Unions, had the intention of applying for affiliation as a Special Union to the I.C.S.U. It was hoped that this affiliation would be effected; but even if this were not possible, it seemed that the existing societies in Britain and the Netherlands (and, it was hoped, the American Society), together with small groups which would be organized in a number of other countries, could form a Union which, though initially limited in size and financial scope, could contribute substantially to the benefit of international rheology.

One of the first activities was to be the merging of our British Bulletin into an International Abstract Bulletin which could be wider in scope and circulation and therefore more economical to run than our own Bulletin. When I was elected President of the B.R.C. two years ago, having less onerous duties than I had had as Editor, I promised to give much of my spare time to getting the Union started, not only as its provisional Secretary, but especially in seeking financial support in this country.

Unfortunately, I had no sooner thrown myself wholeheartedly into this work than I became ill and, for about a year, was obliged to give up all scientific activities apart from my own job (which I was fortunately able to continue).

By the time I was back to normal health, a number of events had taken place which changed the situation. The President of the new Union, Professor J. M. Burgers and his friend Professor Hermans, who were among the most active workers for the Union on the Continent, were in America, with the result that very little further work was done in Europe. Moreover, the American rheologists were not prepared to support the Union, nor to join in the running of the Bulletin. Though we were very sorry to hear of this decision, most of us felt, I think, that Britain, the Netherlands, France, Switzerland, the Scandinavian countries and perhaps Israel could form a very effective little Union even without the support of U.S.A. or U.S.S.R. (we had entirely failed to establish contact with Russia). The Union would presumably not be attached to the I.C.S.U.

I was disappointed in my hope that there would be a meeting of the Joint Committee in the summer of 1951 but was fortunate enough to see Professor Hermans, and I gathered from him and from letters from Professor Burgers that the other European countries, including the Netherlands, did not feel that they could profitably continue with any kind of Union without American support.

Recent letters from Professor Burgers suggested that, instead of a Union, we should have an "Association". There would be no abstract Bulletin, but the Association would issue some kind of information leaflets to keep contact between rheologists in member-countries. The Association would have to be affiliated to one of the big Unions, probably Applied Mechanics. The Committee of our Society, after careful consideration, did not feel that this scheme, which would probably cost us as much as membership of a Union, would have much to recommend it. We were hoping to have more information to put before our members at Exeter: we should like to have had the views of a meeting of the Joint Committee. As it is, there was little that we could discuss and it seems that our Society will have to continue with an independent editorial policy for another year. I sincerely hope that the summer of 1952 may see some representative international meeting of European rheologists at which these matters will be fully debated.

May I conclude by saying how much I welcome your recent editorial on international science? Science has always been an international brotherhood. If certain members of the family of nations refuse to cooperate, the rest of us, while never despairing of an eventual world-wide organization, should, I feel, federate as closely as possible amongst ourselves, in order "to soften the asperities of international strife" (I quote Davy from memory). Only so can science play its part in checking the present disastrous and headlong rush towards the destruction of our civilization.

G. W. SCOTT BLAIR.

2099. **Annual report 1950 "Central Institute for Physico-Chemical Constants."**
Chem. Weekblad, 1951, **47**, 549.

The experimental research concerning accurate viscosity measurement with Ostwald viscometers of small liquid content (5 ml) directed by Prof. J. Th. G. Overbeek was concluded. The most important results are :

(a) With a series of 5 viscometers viscosity measurements of Newtonian liquids is possible with an accuracy of 0.2%.

(b) The kinetic energy correction is about 40% smaller than the BSS no. 188 value, but about 20% larger than Bingham, Cannon and Fenske's value (*Oil and Gas J.* 1935, **33**, 52).

(c) For a "drainage effect" with high viscosity liquids an empirical correction is given.

(d) The calibration tables of Bingham and Jackson differ systematically.

P.G.M.

2100. **A viscometer for clay slips.**

Ceramics 1950, **2**, 540.

The Techne viscometer is described. Its range is claimed to be 50 cp to 2000 poises.

2101. **The deformation of gold wire at high temperature.**

B. H. ALEXANDER, M. H. DAWSON AND H. P. KLING. *J. Appl. Phys.*, 1951, **22**, 439.

2102. **Integral equations for the deformation vector in the statics of an isotropic elastic body.**

I. S. ARZHANYKH. *Dokl. Akad. Nauk, SSSR*, 1950, **75** (6), 783. *In Russian.*

Subject to the existence of boundary conditions expressible in terms of Green's functions, the deformation vector of an isotropic elastic body can be expressed explicitly in the form of an integral equation. This is done in two cases : (i) when the surface deformation is specified; (ii) when derivatives of the deformation are specified. An integro-differential equation defining the specific energy of deformation is also derived.

SCI. ABSTR.

2103. **The axis of distortion of a twisted elastic prism.**

D. G. ASHWELL. *Phil. Mag.*, 1951, **42**, 820.

2104. **Viscosity of sodium thymonucleate.**

E. BASU. *Nature*, 1951, **168**, 341.

2105. **A theory of the plastic distortion of a polycrystalline aggregate under combined stresses.**

J. F. W. BISHOP AND R. HILL. *Phil. Mag.*, 1951, **42**, 414.

2106. **A nomogram for calculating the stiffness of elastomers.**

T. B. BLEVINS AND M. G. DE FRIES. *Bull. Amer. Soc. Test. Mater.*, 1951 (April), p. 59.

2107. **Visco-elasticity of rubber.**

R. B. BLIZARD. *J. Appl. Phys.*, 1951, **22**, 730.

2108. **On the theory of dislocations.**

J. L. BOGDANOFF. *J. Appl. Phys.*, 1950, **21**, 1258.

2109. **Friction of clean metals and the influence of adsorbed films.**

F. P. BOWDEN AND J. E. YOUNG. *Proc. Roy. Soc. A*, 1951, **208**, 311.

2110. **Friction of diamond, graphite, and carbon and the influence of surface films.**

F. P. BOWDEN AND J. E. YOUNG. *Proc. Roy. Soc. A*, 1951, **208**, 444.

2111. **The "Empirical Flow Test" in printing ink technology.**

R. F. BOWLES. *J. Oil Col. Chem. Assoc.*, 1951, **34** (374), 339.

The Empirical Flow Test, which gives a log stress/time curve as obtained with a coaxial cylinder viscometer, has been used to study the behaviour of printing inks over a wide range of shear rates. In particular, matters studied are low-stress behaviour of inks in the duct of the printing machine, batch control of consistency, efficiency of grinding processes and the mechanism of ink distribution. D.L.T.

2112. **Some observations on wetting and dispersion with particular reference to titanium oxide.**

A. BOWMAN AND W. HUGHES. *J. Oil Col. Chem. Assoc.*, 1951, **34** (375), 412.

Wetting and dispersion are terms loosely applied in the paint industry and an improved terminology is suggested. The ionic theory of the mechanism of stabilization of aqueous suspensions of TiO_2 pigment is discussed and correlated with experimental observations on factors affecting the stability. The theory is extended to describe the stabilization of suspensions in non-aqueous media in terms of orientated adsorbed dipoles. The electrical potentials of the adsorbed layers have been investigated experimentally by measurements of streaming potentials. The effects on rheological properties are discussed. D.L.T.

2113. **Relation of tensile strength to brittle temperature in plasticized polymers.**

R. F. BOYER. *J. Appl. Phys.*, 1951, **22**, 723.

2114. **Viscosity and density of lubricating oils from 0 to 150,000 psig and 32° to 425°F.**

D. BRADBURY, M. MARK AND R. V. KLEINSCHMIDT. *Trans. Amer. Soc. Mech. Engrs.*, 1951 (July), p. 668.

This is a summary of work done at Harvard University under an ASME grant sponsored by the Special Research Committee on Lubrication. The original programme, involving some 46 specimens, is nearing completion and a complete report will be published later. Viscosities and densities were measured in pressure equipment of the type used by Bridgman over the ranges stated. Viscosities were limited to a range of about 4.5 to 540,000 centipoises: normally shear stresses could be varied by 40:1, but in a special apparatus this could be extended to 2000:1. Specimens included oils for gear or friction tests, narrow cut paraffinic and naphthenic lubricant type oils, several oils with additives and several pure compounds. The apparatus and method of use are described in detail. A general empirical equation connecting viscosity, temperature and pressure is developed. V.G.W.H.

2115. **Viscosity behaviour of gases.**

L. A. BROMLEY AND C. R. WILKE. *Ind. & Eng. Chem.*, 1951, **43**, 1641.

2116. **The role of surface active agents in pigment dispersions.**

W. CARR. *J. Oil Col. Chem. Assoc.*, 1951, **34** (375), 400.

An outline is given of the principles underlying the use of surface active agents in producing suspensions of pigment in aqueous and non-aqueous media (particularly media of low polarity) to give improved grinding facility, lower oil absorption and lower viscosity for the same pigment concentration. D.L.T.

2117. **The development of deformation textures in metals: II. Body-centred cubic metals.**
E. A. CALNAN AND C. J. B. CLEWS. *Phil. Mag.*, 1951, **42**, 616.
2118. **The development of deformation features in metals: III. Hexagonal structures.**
E. A. CALNAN AND C. J. B. CLEWS. *Phil. Mag.*, 1951, **42**, 919.
2119. **Scheme for analyzing capillary measurements on non-newtonian liquids.**
O. H. CLARK AND M. L. DEUTSCH. *J. Appl. Phys.*, 1950, **21**, 1195 (letter).
2120. **Original authorship of formulas given in Clark and Deutsch's paper.**
M. REINER AND G. W. SCOTT BLAIR. *J. Appl. Phys.*, 1950, **21**, 1195 (letter).
2121. **Lubrication at extreme pressures with mineral oil films.**
O. H. CLARK, W. W. WOODS AND J. R. WHITE. *J. Appl. Phys.*, 1951, **22**, 474.
2122. **Deformations and stresses in bourdon tubes.**
R. A. CLARK AND E. REISSNER. *J. Appl. Phys.*, 1950, **21**, 1340 (letter).
2123. **Primary creep and stiffness of vulcanized rubbers.**
D. H. COOPER. *Ind. & Eng. Chem.*, 1951, **43**, 365.
2124. **A mechanism for the growth of deformation twins in crystals.**
A. H. COTTRELL AND B. A. BILBY. *Phil. Mag.*, 1951, **42**, 573.
2125. **Poisson's ratio and electrical resistance.**
J. R. H. COUTTS AND J. A. V. FAIRBROTHER. *Proc. Phys. Soc., Lond. B*, 1951, **64**, 530 (letter).
2126. **Elasticity of soft polymers.**
C. A. DAHLQUIST, J. O. HENDRICKS AND N. W. TAYLOR. *Ind. & Eng. Chem.*, 1951, **43**, 1404.
2127. **Densities and viscosities of solutions of the zinc halides in methanol from -50° to 20° .**
L. R. DAWSON, H. K. ZIMMERMAN, W. E. SWEENEY AND G. P. DINGA. *J. Amer. Chem. Soc.*, 1951, **73**, 4326.
2128. **Cracking of stressed polyethylene.**
J. B. DECOSTE, F. S. MALM AND V. T. WALLDER. *Ind. & Eng. Chem.*, 1951, **43**, 117.
2129. **Butadiene-styrene copolymers.**
J. D. D'IANNI, L. D. HESS AND W. C. MAST. *Ind. & Eng. Chem.*, 1951, **43**, 319.
Physical properties determined of copolymers containing more than 50% styrene. These include tensile strength, elongation, hardness, stiffness, impact strength and heat distortion point. F.H.
2130. **The tensile strength of benzene.**
J. J. DONOGHUE, R. E. VOLLRATH AND E. GERJUOY. *J. Chem. Phys.*, 1951, **19**, 55-61.
The centrifuge method is described, together with various features which have been incorporated into the procedure to insure uniformity of samples. There is evidence, which is not conclusive, however, that the rupture strength increases as the amount of permanent gas dissolved in the liquid decreases. The highest observed rupture strength,

157 atmosphere, is believed to represent the adhesion strength of the benzene to the walls of a particular tube, and may be much less than the limiting tensile strength of benzene. No evidence for a temperature dependence of the tensile strength has been found, but this result is probably also not representative of the limiting tensile strength of benzene.

AUTHORS.

2131. Studies in Newtonian flow. I. The dependence of the viscosity of liquids on temperature.

A. K. DOOLITTLE. *J. Appl. Phys.*, 1951, **22**, 1031.

2132. Determination of intrinsic low stress properties of rubber compounds.
W. B. DUNLAP, JR., C. J. GLASER, JR. AND A. H. NELLEN. *Anal. Chem.*, 1951, **23**, 638.

The test, which is made on an inclined plane tester under constant conditions of temperature and humidity, measures initial load and load on recovery accurately at low stress. Autographic recording of data. The range of properties examined approximates conditions under which tyre stocks operate in service.

2133. The flow properties of elastic dispersions.

W. J. DUNNING AND D. PATTERSON. *Trans. Faraday Soc.*, 1950, **46**, 1095.

Flow properties of dispersions of latex rubber in Aroclor 4465 (10^{10} poises) have been studied.

2134. Rheometric tests and extrusion.

S. ECCHER. *Ind. & Eng. Chem.*, 1951, **43**, 479.

Cylindrical rheometer of the Couette type used with natural and synthetic rubbers and mixtures of both with various fillers. Reasonable agreement found between values of flow and pressure determined with an extruder and those calculated from parameters determined with the cylindrical rheometer.

2135. Dynamic properties of raw and vulcanized polymers.

R. S. ENABNIT AND S. D. GEHMAN. *Ind. & Eng. Chem.*, 1951, **43**, 346.

Test uses low amplitude shear vibrations at 60 cycles. Definite correlation between the dynamic properties of a series of raw polymers and those of vulcanized gum and tread stocks prepared from them. Effect of cure measured.

2136. Effect of synthetic elastomers on properties of petroleum asphalts.

H. A. ENDRES, R. J. COLEMAN, R. M. PIERSON AND E. A. SINCLAIR. *Ind. & Eng. Chem.*, 1951, **43**, 334.

2137. Viscosity of the sodium-potassium system.

C. T. EWING, J. A. GRAND AND R. R. MILLAR. *J. Amer. Chem. Soc.*, 1951, **73**, 1168.

Viscosity measurements are given for sodium, potassium and several alloys from 60° or the melting point to 200°C. The temperature variation was in accord with Andrade's equation.

E.W.J.M.

2138. Nonclassical reaction kinetics.

H. EYRING AND P. GIBBS. *Science*, 1951, **113**, 104.

The interpretation of the plastic flow of metals by Eyring and Fredrickson assuming a classical expression for the rate of passage across an energy barrier is altered by using the quantum mechanical expression. The effective potential energy V to prevent motion is assumed to be relaxed at every point by an amount proportional to the stress, to relax the stress. This is due to the local distortion. The new expression gives the correct temperature dependence naturally. Since electrical conductivity can be treated in a similar fashion an analogy is set up between the variation with composition in alloys of the hardness and resistivity. This is borne out by the experimental curves.

SCI. ABSTR.

2139. **Mechanical properties of substances of high molecular weight. X. The relaxation distribution function in polyisobutylene and its solutions.**
J. D. FERRY, E. R. FITZGERALD, M. F. JOHNSON AND L. D. GRANDINE. *J. Appl. Phys.*, 1951, **22**, 717.
2140. **On the Fredrickson-Eyring theory of the mechanical behaviour of metals.**
J. FLEEMAN AND G. J. DIENCES. *J. Appl. Phys.*, 1950, **21**, 1193 (letter).
2141. **Treatment of intrinsic viscosities.**
P. J. FLORY AND T. G. FOX. *J. Amer. Chem. Soc.*, 1951, **73**, 1904.
An improved derivation is given for the relationship between the configurational dimensions of a polymer molecule in solution and the thermodynamic interaction between polymer segments and solvent molecules. The root-mean-square end-to-end distance for the polymer molecule when the net thermodynamic interaction between segments and solvent is zero may be computed from suitable viscosity measurements.
E.W.J.M.
2142. **Intrinsic viscosity-temperature relationships for polyisobutylene in various solvents.**
T. G. FOX AND P. J. FLORY. *J. Amer. Chem. Soc.*, 1951, **73**, 1909.
Intrinsic viscosities of polyisobutylene fractions have been determined in pure solvents and their mixtures over wide temperature ranges. Values of interaction parameters are given.
E.W.J.M.
2143. **Intrinsic viscosity relationships for polystyrene.**
T. G. FOX AND P. J. FLORY. *J. Amer. Chem. Soc.*, 1951, **73**, 1915.
Intrinsic viscosities of polystyrene fractions have been determined in various solvents at several temperatures. The polystyrene molecule appears to be more extended than is one of polyisobutylene having the same number of chain atoms. E.W.J.M.
2144. **The effect of rate of shear on the viscosity of dilute solutions of polyisobutylene.**
T. G. FOX, J. C. FOX AND P. J. FLORY. *J. Amer. Chem. Soc.*, 1951, **73**, 1901.
Specific viscosities of dilute solutions of polyisobutylene fractions decrease approximately linearly with the rate of shear over the range from several hundred to several thousand sec^{-1} . The "shear coefficient" ϕ , conveniently defined as $100 \times d(\log \eta_{sp})/\dot{\gamma}$ is independent of concentration at low concentrations. The log of η_{sp} decreases non-linearly with $\dot{\gamma}$ for dilute solutions of polyisobutylene of very high molecular weight.
2145. **Crystal dislocations—elementary concepts and definitions.**
F. C. FRANK. *Phil. Mag.*, 1951, **42**, 809.
2146. **Plasticity and conductivity, analogous flow phenomena in copper alloys.**
R. S. FRENCH. *J. Appl. Phys.*, 1951, **22**, 105 (letter).
2147. **The paint/vehicle problem.**
J. S. GOURLAY. *J. Oil Col. Chem. Assoc.*, 1951, **34** (375), 385.
Following a survey of fundamental methods of approach to paint problems, the results of some investigations are reported. Examination, on a new viscometer, of rheological properties of suspensions of glass and quartz spheres indicates that systems containing only large particles are Newtonian up to 50% volume concentration of particles, but systems involving particles less than 0.1μ in size show thixotropy at 3% concentration. Effects of varying pigment and resin content on viscous properties of paints and on gloss of dried films are illustrated.
D.L.T.
2148. **The use of plasticine models to simulate the plastic flow of metals.**
A. P. GREEN. *Phil. Mag.*, 1951, **42**, 365.

2149. **A theoretical investigation of the compression of a ductile material between smooth flat dies.**

A. P. GREEN. *Phil. Mag.*, 1951, **42**, 900.

2150. **The quantum mechanics of assemblies of interacting particles.**

H. S. GREEN. *J. Chem. Phys.*, 1951, **19**, 955.

2151. **An automatic light-load Bergsman type hardness tester.**

P. GRODZINSKY. *J. Sci. Instrum.*, 1951, **28**, 117.

2152. **On creep and relaxation. III.**

B. GROSS AND H. PELZER. *J. Appl. Phys.*, 1951, **22**, 1035.

2153. **Viscosity of fire-fighting foam.**

C. S. GROVE, Jr., G. E. WISE, Jr., W. C. MARSH AND J. B. GRAY. *Ind. & Eng. Chem.*, 1951, **43**, 1120.

2154. **Empirical analysis of viscosity data.**

H. T. HALL AND R. M. FUOSS. *J. Amer. Chem. Soc.*, 1951, **73**, 265.

The Wilberforce equation $\eta = apt - m\beta/t$, where m is practically unity, is accepted as a summary of experimental evidence. The equation is transformed to

$$1/pt = A/\eta - A'\rho p/\eta^3$$

which states that a Newtonian liquid in a viscometer which needs correction for kinetic energy and end effects will show that apparent fluidity is linear in p and the true value of $1/\eta$ is obtained by extrapolating $1/pt$ to zero pressure and dividing by the instrument constant A . A method is described for the experimental evaluation of these corrections. Plots show the variations obtained in m with a large number of liquids. Using polymer solutions a dependence of apparent viscosity on the rate of shear is demonstrated. At a pressure p the intrinsic viscosity of a polymer is $[\eta]_a (1 - kp)$, k being a single arbitrary constant.
E.W.J.M.

2155. **On combined bending and twisting of thin tubes in the plastic range.**

D. HILL AND M. P. L. SIEBEL. *Phil. Mag.*, 1951, **42**, 722.

2156. **On the state of stress in a plastic-rigid body at the yield point.**

R. HILL. *Phil. Mag.*, 1951, **42**, 868.

2157. **The variation of the dynamic elasticity of polythene with strain.**

K. W. HILLIER. *Brit. J. Appl. Phys.*, 1951, **2**, 167.

2158. **The application of rate-process theory to glass. II. Viscosity.**

F. B. HODGDON AND D. A. STUART. *J. Appl. Phys.*, 1950, **21**, 1160.

2159. **A continuous flow, high temperature viscosimeter for drilling muds.**

R. W. HOEPEL. *Rev. Sci. Instrum.*, 1951, **22**, 248.

A continuous-flow tube viscosimeter is described which permits determination of viscosities and gel strengths of abrasive thixotropic fluids at temperatures up to 250°F. Provision is made for the introduction of treating chemicals into the closed system, while under pressure, without interrupting fluid flow. The new instrument employs a special rubber tube pump which maintains constant flow under various pressures and is unaffected by abrasive materials. Flow characteristics of the pump are discussed, and tube and Stormer viscosimeter data are compared.
AUTHOR.

2160. **Dynamic shear properties of rubberlike polymers.**

I. L. HOPKINS. *Trans. Amer. Soc. Mech. Engrs.*, 1951, **73**, 195.

A simple apparatus for determining the dynamic properties of elastomers in shear at audio frequencies is appraised. Typical values of shear modulus and viscosity for several elastomers are given, both at room conditions and at 150°F. The frequencies of test range from 100 to 5 250 c/s, the shear moduli from 0.5×10^6 to 480×10^6 dynes/cm² and the viscosities from 20 to 75 000 poises.
AUTHOR.

2161. **Viscoelastic properties of several high polymers.**
M. HORIO, S. ONOGI, C. NAKAYAMA AND K. YAMAMOTO. *J. Appl. Phys.*, 1951, 22, 966.
2162. **The plastic theory of bending of mild steel beams with particular reference to the effect of shear forces.**
M. R. HORNE. *Proc. Roy. Soc. A*, 1951, 207, 216.
2163. **On crazing of linear high polymers.**
C. C. HSIAO AND J. A. SAUER. *J. Appl. Phys.*, 1950, 21, 1071.
2164. **A theory of the dynamic plastic deformation of a thin diaphragm.**
G. E. HUDSON. *J. Appl. Phys.*, 1951, 22, 1.
2165. **Some factors affecting microhardness values.**
B. B. HUNDY. *Metallurgia*, 1951, 43 (256), 99.
- Factors affecting microhardness values are : accuracy of measurement of impression, effects inherent in specimen, effects in operation during indentation, external effects. Impression best measured by projecting image of indentation at standardized magnification of $1,000\times$ on to mm grid screen. This permits measurement to 0.5 micron, equivalent to error to 0.6 VPN in hardness 50 and 20 in hardness 500. Specimen should be given a metallographic polish. Found that hand polishing of soft metals such as annealed Cu gave high hardness values due to work-hardened surface layer. Electro-polished surface gave true values. Effect not detected in mild steel. Hardness of grain boundaries shown to be rather greater than hardness of centre of grains, and hardness of single grain may depend on its orientation and hardness of neighbouring grains. For loads less than 100 g, diamond pyramid must have perfect point and not chisel edge. Axis of indenter must be exactly perpendicular to specimen, and in beam-type testers load must be applied directly above point of contact with indenter. When load applied by fine-focusing screw on Vickers projection microscope, rate of loading had little effect on hardness value, 10-15 micron/sec being convenient rate. Hardness values for materials of low yield strength affected by time of indentation; 30 and 15 sec recommended for soft and hard metals respectively. Increasing applied load generally gives increase in hardness value, effect being particularly pronounced with highly worked materials. When making test, indenter should be raised several micron after making contact with specimen, as otherwise creep of metal round indenter may cause some load to be taken by electrical contacts on beam. Care should be taken that impression is not enlarged by vibration of instrument or mechanical fault in fine-focusing screw, errors from these causes being shown. When all factors standardized and precautions taken as indicated, reproducible results obtainable with balanced beam microhardness tester. I.D.I.B.

2166. **On the transverse stresses which develop in tensile tests.**
B. JAOU. *C.R. Acad. Sci., Paris*, 1951, 232, 477. *In French*.

Experiments on the plastic elongation of Al test pieces showed that the ratio diametral contraction/longitudinal extension was $\frac{1}{2}$ for solid cylinders and $\frac{1}{3}$ for very thin-walled tubes. This indicates the existence of important transverse stresses in the cylinder. Calculations based on the forces required to produce plastic deformation in the two cases are regarded as verifying the von Mises' yield criterion.

SCI. ABSTR.

2167. **Creep of high-purity aluminium.**
W. D. JENKINS. *J. Res. Nat. Bur. Stand., Wash.*, 1951, 46, 310.

A study was made of cold-drawn aluminium at 105°F, to determine the effects of variations of creep rate on the mechanism of deformation. Strain-hardening was found to decrease monotonically with increase in strain during first stage of creep. The extension on loading and the extension at the beginning of the third stage both increased with increase in stress. Cyclic temperature changes appeared to increase the ductility. Discontinuous flow was evidenced in constant-load creep tests at 105°F and in tensile tests conducted at 80°F. Conformance to Andrade's law of transient flow was found

within a limited range of strain rates. Sigmoidal curves were produced that depicted the relationship between stress and creep rate. A mechanism of flow based on observed structural changes is proposed. SCI. ABSTR.

2168. Viscosities of liquids at constant volume.

A. JOBLING AND A. S. C. LAWRENCE. *Proc. Roy. Soc. A*, 1951, **206**, 257.

2169. GR-S aging in solution.

G. D. JONES AND R. I. FRIEDRICH. *Ind. & Eng. Chem.*, 1951, **43**, 1600.

Claimed that the work has led to a better understanding of the viscosity changes which occur in GR-S solutions on standing. Photodegradation of solution occurs only in presence of oxygen and two types of peroxide are formed.

2170. The viscosity and internal friction of solids.

A. KAMMERER. *C.R. Acad. Sci., Paris*, 1950, **231**, 1285. *In French*.

If the elastic modulus decreases more rapidly with temperature than the viscosity, then it is shown that the damping of torsional oscillations increases with temperature.

SCI. ABSTR.

2171. The question of the formation of fatigue microcracks.

G. V. KARPENKO. *Dokl. Akad. Nauk, SSSR*, 1950, **74** (1), 95. *In Russian*.

The adsorption theory of stress relief in solid bodies developed by Rebinder *et al.* is applied to explaining the formation of fatigue microcracks. The higher the surface-energy of a solid body the more difficult it is for new microcracks to develop; accordingly the fatigue limit is high. Surface active agents, however, lower the surface energy and therefore facilitate the formation of microcracks. This is confirmed experimentally by submitting steel samples to fatigue tests in the presence of (a) inactive vaseline, (b) vaseline + 2% isoamyl alcohol, and (c) vaseline + 2% oleic acid. The different mechanical treatments of bodies determine the ultramicro-geometry of the surfaces and give rise to different surface-energy distributions and therefore to different conditions for the formation of microcracks, this must be taken into consideration when choosing suitable surface-active agents for different treatments.

SCI. ABSTR.

2172. A new apparatus for the measurement of the elastic modulus and internal friction in solids.

A. KEPES. *Trans. Instrum. Meas. Conf., Stockholm* (1949) 136-8 (1950). *In French*.

A theoretical examination leads to a method in which the specimen is fixed rigidly at one end and a force applied to the free end. The deflection is measured in terms of amplitude and frequency. Methods of measurement are considered and examples given.

SCI. ABSTR.

2173. Methods for determining the hardness of very hard material. The hardness of diamond.

M. M. KHRUSHCHOV, E. S. BERKOVICH. *Zavodskaya Lab.*, 1950 (2), 193. *In Russian*.

Micro-hardness tests with diamond pyramids give quite reliable results for hardness values up to 1,000 kg/sq mm, and even with synthetic corundum (2,000 to 2,200), tungsten carbide (3,200 to 3,400) and boron carbide (about 3,700), no appreciable injury to pyramid noted. Suggested that same methods could be used for still harder materials, of hardness between that of boron carbide and diamond, and even for diamond itself. Some experiments described, after brief ref to literature on testing diamond hardness, *eg* F. Auerbach, F. Knoop, and O. Bernhardt. Auerbach using load of 1,000 g found diamond hardness of 2,500 kg/sq mm, Knoop of 8,200 to 8,500 kg/sq mm, and Bernhardt hardness of 10,000 kg/sq mm and modulus of elasticity about 80,000 kg/sq mm on diamond face (111) with load of 200 g. In present tests both square base and triangular base pyramids used, first with face angle of 136 deg and second with 65 deg angle between vertical axis and side, used in hardness tester PMT-2. Proved difficult to obtain perfect intersection of all facets in square pyramid, and point therefore imperfect. Value of H with this was $1854.P/d^2$ kg/sq mm and with triangular pyramid $1570.P/l^2$

kg/sq mm (l height of triangle normal to base). Loads were 50, 100, 200, and 500 g. With 200 and 500 g loads some damage to point, with blurred impressions, resulted: but less for triangular pyramid than for square: and latter proved much more suitable for small impressions; though even in this case margin of error appreciable, *ie* for measurements of 4 micron or less. Considered that, in any case, numerical evaluation of diamond hardness increases with decreasing dimensions of impressions and that with square pyramid larger figures are obtained than with triangular, under same load. Ref to significance of "resilient recovery" in these experiments, and to probable increase in surface hardness of diamond (work-hardening), such as in polishing facets to obtain point again after wear or damage. Provisionally concluded that hardness value of diamond, as result of these tests, is about 10,000 kg/sq mm. I.D.I.B.

2174. The visco-elastic properties of solutions of rod-like macromolecules.

J. G. KIRKWOOD AND P. L. AUER. *J. Chem. Phys.*, 1951, **19**, 281.

The general theory of irreversible processes in solutions of macromolecules is employed to investigate the visco-elastic behaviour of solutions of rod-like macromolecules. It is found that rotatory diffusional torques are responsible for three-fourths of the stationary intrinsic viscosity. Under the action of periodic shear waves, the rotatory diffusional contribution to the stress exhibits relaxation phase lag and imparts a rigidity to the solution. As the frequency is increased, the intrinsic viscosity drops to one-fourth of its stationary value and the rigidity modulus increases to an asymptotic value of $3RT/5$ per mole/cm³ of solute. AUTHORS.

2175. On the theory of plastic deformation.

D. KUHLMANN. *Proc. Phys. Soc., Lond., A*, 1951, **64**, 140.

2176. Elasticity of crystals.

M. J. LAVAL. *C.R. Acad. Sci., Paris*, 1951, **232**, 1947. *In French.*

A note stating certain results obtained from an atomic displacement treatment. In general, 45 elastic coefficients are required for a crystalline medium, and not 21, as derived by Voigt, but for the particular case of central forces between atoms, certain coefficients conform with those of Voigt, and the medium can be treated classically. SCI. ABSTR.

2177. Use of the pendulum for investigations of surface hardness.

P. LE ROLLAND. *Chrome Dur.*, 1950-1951, pp. 7-15. *In French.*

Main feature of electrolytically deposited chromium is hardness reaching Brinell hardness 800 kg/sq mm (Rockwell 70), compared with 300 kg/sq mm for cobalt deposit. Definition of hardness; stressed that same testing method applied to different materials may give contradictory results: Shore rebound test applied to human finger would prove it harder than steel; Brinell test applied to rubber (no permanent impression) would classify it as infinitely hard. Therefore suggests testing hardness by duration of oscillations, pendulum being suspended from very hard roller (or ball) placed on test surface. Oscillation rate increases with support softness; observation of small amplitudes sufficient. Mathematical basis for theory and description of different types; especially double pendulum models (photographs). One model fitted with control pendulum swinging on diamond support with spherical top; both pendulums can be lifted simultaneously from swinging supports by cam action; contact with diamond possible without acceleration when lowered. Later model fitted with conical diamond 120 deg included angle and top radius of 0.2 mm (similar to Rockwell cone). Weight applied in range of 5.5 kg (12 lb.); important as test piece may be permanently marked when chrome deposit only very thin. To keep results accurate, further weight decrease not advisable. Impressions of 6 micron size belong to microhardness range. Test results for different thicknesses of chromium deposits with hardness values for pendulum, Brinell and Vickers test, and microsclerometer (R. Girschig). Hardness of deposit depends on rate of electrolytic process, *ie* density of current employed. I.D.I.B.

2178. Fluid dynamics.

M. LEVA AND M. WEINTRAUB. *Ind. & Eng. Chem.*, 1951, **43**, 90.

A review of recent literature covering most aspects of fluid dynamics, emphasis being on engineering problems. 344 refs. F.H.

2179. A micro-indentation hardness tester for attachment to the Vickers projection microscope.

S. J. LLOYD AND D. J. NORRIS. *J. Sci. Instrum.*, 1951, **28**, 81.

2180. Creep properties of lucite and plexiglas for tension, compression, bending and torsion.

J. MARIN, YOH-HAN PAO AND G. CUFF. *Trans. Amer. Soc. Mech. Engrs.*, 1951 (July), p. 705.

Creep tests were made at $77 \pm 2^\circ\text{F}$ and R.H. $50 \pm 2\%$. Deformation-time plots are shown for tension, compression, bending and torsion: values of the deformations are shown for periods of 1000 hr and include both the elastic and creep deformations for a range of stress values. After the initial creep, the creep rate remains practically constant. The relation between creep rate and stress is linear on a log-log plot and the total creep strain ϵ at time t can be represented by the equation

$$\epsilon = D_t S_t m_t + B_t t S_t n_t$$

where D_t , m_t , B_t and n_t are the creep constants in tension creep. Compression creep can be represented by the same equation with different values of the constants, now written D_c , m_c , etc. A theory is developed for predicting the creep deflexion rates in bending based on different creep constants in tension and compression. Torsion-creep results could not be correlated with tension-creep data because the materials tested were not in the same condition. Some criticisms of the paper are made in the discussion.

V.G.W.H.

2181. Influence of molecular weight on the properties of polystyrene.

E. H. MERZ, L. E. NIELSEN AND R. BUCHDAHL. *Ind. & Eng. Chem.*, 1951, **43**, 1396.

2182. A relationship between heat conductivity and viscosity of liquids.

S. R. MOHANTY. *Nature*, 1951, **168**, 42.

2183. Comment on "Relationship between Gough-Joule coefficients and moduli of vulcanized rubbers".

M. MOONEY. *J. Appl. Phys.*, 1950, **21**, 1338.

2184. The distribution of plastic deformation in a sample of iron under tension, showing the Piobert-Luders effect.

M. MOUFLARD AND P. LACOMBE. *C.R. Acad. Sci., Paris*, 1950, **231**, 1500. *In French.*

On increasing the tension beyond a certain limit, giving say $a\%$ elongation, the sample no longer deforms uniformly; it is crossed by bands in which the elongation is $b\%$, a considerably greater amount. The effect of an increase in tension is to broaden these bands, thus causing an overall elongation of between $a\%$ and $b\%$. When the total elongation reaches $b\%$, ie the bands occupy the whole sample, further increases in tension produce a uniform elongation.

SCI. ABSTR.

2185. The theory of non-linear elasticity.

Y. NAKAGAWA. *Mem. Fac. Engng. Kyoto Univ.*, 1950, **12**, 66.

A simple explanation is given, in terms of inter-molecular forces, of non-linear stress-strain relations suitable for describing the general elastic behaviour of (eg) cast iron and concrete.

SCI. ABSTR.

2186. An approximation method for the determination of the elastic constants of cubic single crystals.

J. R. NEIGHBOURS AND C. S. SMITH. *J. Appl. Phys.*, 1950, **21**, 1338 (letter).

2187. **The plastic deformation of pure single crystals of lead and copper.**
P. W. NEURATH AND J. S. KOEHLER. *J. Appl. Phys.*, 1951, 22, 621.

2188. **Molecular structure of styrene-butadiene copolymers.**

L. E. NIELSEN, R. BUCHDAHL AND G. C. CLAVER. *Ind. & Eng. Chem.*, 1951, 43, 341.

Dynamic shear modulus, mechanical damping, swelling properties in benzene and infra-red spectra have been determined on a series of styrene-butadiene copolymers which were prepared under a variety of polymerization conditions. It may be possible to prepare a polybutadiene rubber which retains its rubber-like properties down to -120°C .

2189. **Rotation of an infinite plane lamina: boundary layer growth: motion started impulsively from rest.**

S. D. NIGAM. *Quart. Appl. Maths.*, 1951, 9, 89.

A discussion of the growth of motion in the earlier stages of its development when the lamina is suddenly made to rotate with constant angular velocity about an axis perpendicular to its plane. The solutions obtained only apply to the initial motion, and hence given no information as to the time required to reach the steady state for which exact solutions have been obtained by T. v. Karman. R.R.

2190. **Effect of free surface on the yielding resistance of materials.**

T. NISHIHARA AND S. TAIRA. *Mem. Fac. Engng. Kyoto Univ.*, 1951, 12, 90.

Stress measurements by X-ray methods on steels and Al deformed plastically in tension or compression indicate a non-uniform distribution of stress over the cross-section. This is deduced to be a consequence of the restrictive influence exerted by neighbouring grains, such that the surface grains can deform more easily than those in the interior. A theoretical treatment based on the concept of a yielding resistance as applied to a mosaic of blocks (grains) is set out and some quantitative results deduced which, in the authors' view, justify the theory. SCI. ABSTR.

2191. **Formula for correlating the viscosity of silicate glasses and temperature.**

M. V. OKHOTIN. *Dok. Akad. Nauk USSR*, 1950, 71, 527.

Three formulae are given: one suggested by Frenkel (1926), another by Khaikin (1936), and one which is suggested by the author. Examples show the use of each formula for calculations with sheet glass of a certain comp. The results found by each formula are tabulated and it is concluded that the first 2 formulae are inaccurate insofar as they give values which disagree considerably with those found experimentally, whereas the last one is considered suitable for the determination of the viscosity of silicate glasses, and of other liquids also. B.C.R.A.

2192. **A coaxial-cylinder elastoviscometer.**

J. G. OLDROYD, D. J. STRAWBRIDGE AND B. A. TOMS. *Proc. Phys. Soc., Lond.*, 1951, 64, 44.

2193. **Rectilinear flow of non-Bingham plastic solids and non-Newtonian viscous liquids. II.**

J. G. OLDROYD. *Proc. Camb. Phil. Soc.*, 1951, 47 (2), 410.

The equation of steady rectilinear motion of a material of variable viscosity is transformed, when the pressure gradient vanishes, into a second-order differential equation which is linear in the dependent variable. A general solution of the linearized equation can be obtained in the case of a wide class of plastic solids and viscous liquids. By making use of the idealized materials which lend themselves to this method of solution, a theoretical comparison can be made of the behaviour of plastic solids of different types under the same conditions. As an illustration, a plastic solid which yields very sharply when the yield point is first exceeded is compared with one which yields only

gradually at the same yield value; the flow caused by the longitudinal motion of an (approximately) elliptic cylinder in an infinite mass of material is investigated in each case.

AUTHOR.

2194. On the friction of various synthetic and natural rubbers on ice.

P. M. PFALZNER. *Canad. J. Res., F*, 1950, **28**, 468.

The dynamic and static friction on ice, the hardness, and the resilience of natural and synthetic rubber tyre compounds were measured. General relationships were found to exist between friction and hardness of the rubber, friction and ice temperature, hardness and temperature, hardness and age of the rubber, resilience and hardness. Extraction of the rubber had a variable effect.

AUTHOR.

2195. Erratum to mechanical properties of glass.

F. W. PRESTON. *J. Appl. Phys.*, 1951, **22**, 48.

2196. The concentration dependence of the viscosity of solutions of macromolecules.

J. RISEMAN AND R. ULLMAN. *J. Chem. Phys.*, 1951, **19**, 578.

The theory of the concentration dependence of the viscosities of solutions is developed for the dumb-bell, rigid rod, and flexible chain macromolecules. Both the intramolecular hydrodynamic interactions between the monomer units of the same molecule and the intermolecular interactions between monomer units of different molecules are considered. The methods of Riseman and Kirkwood are applied throughout. The numerical result of the calculation for the dumb-bell shaped molecule is compared with that obtained by Simha.

AUTHORS.

2197. Large elastic deformations of isotropic materials: VII. Experiments on the deformation of rubber.

R. S. RIVLIN AND D. W. SAUNDERS. *Phil. Trans. Roy. Soc. A*, 1951, **243**, 251.

2198. Large elastic deformations of isotropic materials: VIII. Strain distribution around a hole in a sheet.

R. S. RIVLIN AND A. G. THOMAS. *Phil. Trans. Roy. Soc. A*, 1951, **243**, 289.

2199. Mechanics of large elastic deformations with special reference to rubber.

R. S. RIVLIN. *Nature*, 1951, **167**, 590.

2200. Variation of micro-hardness in mono-crystals as function of orientation of a pyramidal indenter.

M. H. ROTH-MEYER. *Comptes Rendus*, 1950, **231** (18), 906. *In French.*

Systematic study made of certain deformations observed in connection with impressions for macro- and micro-hardness tests of monocrystals, using Vickers instrument and metal test-pieces of cubic and hexagonal crystal form. Each crystal face tested with different orientation of indenter. Results recorded for purified Al (99.99%), carefully polished electrolytically. Tests made on faces (100), (110), (111), and appearances found described and illustr. Loads from 100 g to 1 kg. Experiments also made with refined Zn (99.97%). Forms of change observed similar to those found by F. W. Daniels, C. G. Dunn, with other kinds of monocrystals and using Knoop hardness tester. By means of Linnick micro-interferometer, possible to determine maximum thickness of "swelling"—Al face (110) under load of 300 g—namely 2.5 micron for tubular deformation, and 1.8 micron for compass card (*rose des vents*) type: in this way also possible to study lines of slip and of twinning. Concluded that pyramidal indenter with more sensitivity than spheroidal or conical form facilitates detection of variations in hardness, and of impression forms due to anisotropy in crystal, and determination of orientation of crystal faces by lines of slip that appear.

I.D.I.B.

2201. The elastic limit as established by X-ray analysis.

B. M. ROVINSKIĬ AND N. V. TYZHNova. *J. Tech. Phys., USSR*, 1950, **20** (6), 676. *In Russian.*

Investigation of specimens of carbon-steels 45 and 15 in simple tensile stressing verified that the surface layer of the metal in the elastic zone does not yield prematurely; the elastic limit of the surface layer exactly coincides with that of the specimen as a whole. Nor was premature yielding detected on a specimen with a rough surface, the protrusions of which were of the order of magnitude of the penetration depth of the X-rays. When the elastic limit is exceeded by the specimens, this affects the surface layer likewise and is marked by a reduction of the elastic deformation. It was found that the ratio of the lattice deformation to the normal component of the elastic deformation of the specimen, ϵ_R/ϵ_Z , or the ratio of the X-ray stresses to the stresses applied to the specimen, σ_R/σ_M , is determined by the material of the specimen and the micro-relief of its surface.

SCI. ABSTR.

2202. Peculiarities of the change of crystalline structure of a metal on deformation in surface-active media.

V. N. ROZHANSKIĬ, T. A. AMFITEATROVA AND P. A. REBINDER. *Dokl. Akad. Nauk, SSSR*, 1951, **76** (5), 697. *In Russian.*

Thin Cu wire was stretched in a 0.5% solution of oleic acid and in a 0.5% solution of cetyl alcohol, both solvents being kerosene. The degree of plastic deformation was found to be greater than that occurring in an inert medium. The number of grains also increased. It is thought that in a surface-active medium crystallites break down more easily into smaller grains and move more easily relative to one another.

SCI. ABSTR.

2203. Mechanical properties of substances of high molecular weight. IX. Non-Newtonian flow and stress relaxation in concentrated polyisobutylene and polystyrene solutions.

F. W. SCHREMP, J. D. FERRY AND W. W. EVANS. *J. Appl. Phys.*, 1951, **22**, 711.

2204. Viscosity and density of molten optical glasses.

L. SHARTSIS AND S. SPINNER. *J. Res. Nat. Bur. Stand.*, 1951, **46**, 176.

The viscosities and densities of 22 optical glasses, representing all types produced at the National Bureau of Standards, were measured by a counterbalanced-sphere method. The densities agreed with those obtained by a volumeter method, and the viscosities showed good agreement with those obtained with a small rotation viscometer. Expansivities calculated from density results in the temp. range 1,000° to 1,200°C showed that flints are low, 15 to 22, Ba crowns are intermediate, 22 to 37, and borosilicate crowns are high, 34 to 40 (μ/m)/°C. The expansivities showed a positive correlation with the slope of the viscosity/temp. curve. The superiority of the theoretically derived Faxen correction of Stokes' law over that of the empirical Francis formula was established by means of a freely falling sphere apparatus.

B.C.R.A.

2205. Studies on clay-water system, I: Viscosity of Slip, Pt. II.

Y. SHIRAKI. *J. Jap. Ceram. Assoc.*, 1951, **59**, 96. *In Japanese.*

The hydration coeff., Goodeve thixotropy coeff. and surface tension are discussed.

B.C.R.A.

2206. Frictional properties of tungsten carbide and of bonded carbides.

K. V. SHOOTER. *Research, Lond.*, 1951, **4**, 136.

The frictional properties of W carbide and of 4 different bonded carbides have been investigated at slow sliding speeds and under heavy load. The surface damage when carbide and metal slide together is comparable with that found for other softer metals. The presence of the Co in the bonded carbides does not produce any very great difference in behaviour from W carbide itself. Repeated stressing of the bonded carbide leads to a sudden increase of heavy wear and to a rise in friction.

AUTHOR.

2207. **Dry metallic friction as a function of temperature between 4.2°K. and 600°K.**

I. SIMON, H. O. McMAHON AND R. J. BOWEN. *J. Appl. Phys.*, 1951, **22**, 177.

2208. **The effect of certain reagents upon the properties of bentonite colloids. I. Inorganic salts.**

W. H. SLABAUGH AND J. L. CULBERTSON. *J. Phys. Colloid Chem.*, 1951, **55** (5), 744.

The addition of electrolytes to hydrogen bentonite produces: (1) a reduction in the effective diameter of the bentonite; (2) rheological changes in structure, due to base exchange equilibrium between electrolyte and hydrogen bentonite; (3) a change in the bulk structure of the bentonite system, due to modification of the far-reaching forces.

2209. **High temperature viscometer.**

W. H. SPEAR AND L. P. HERRINGTON. *Anal. Chem.*, 1951, **23**, 148.

A viscometer is described that is calibrated at ordinary temperatures but can be used at temperatures over 300°C with an accuracy better than 5%. 70 cc of liquid is used and no high temperature thermostatic baths are needed. Data for three heat transfer liquids are given and compared with previously known information. F.H.

2210. **Elastic constants of gelatinous substances.**

A. M. SRIVASTAVA. *J. Amer. Chem. Soc.*, 1951, **73**, 489.

Elastic constants of iron silicate gel computed from tests made with ultrasonic waves of frequencies 0.625, 1.25, 2.25 and 2.5 Mc/s.

2211. **Solution viscosity and partial specific volume of polystyrene.**

D. J. STREETER AND R. F. BOYER. *Ind. & Eng. Chem.*, 1951, **43**, 1790.

Concentrations of up to 12%.

2212. **Thermal analysis of the system sodium stearate-cetane.**

F. H. STROSS AND S. T. ABRAMS. *J. Amer. Chem. Soc.*, 1951, **73**, 2825.

The phase diagram of dry sodium stearate and cetane indicates that there is no appreciable interaction between soap and medium below 140°C. With a 9% soap in a light oil the viscosity decreased sharply with temperature until the temperature corresponding to the ultimate transmission observed by differential thermal analysis was reached, when there was a further decrease to practically that of the oil. E.W.J.M.

2213. **Elastic constants of orthorhombic sulphur.**

R. V. G. SUNDARA RAO. *Proc. Indian Acad. Sci. A*, 1950, **32**, 275.

The elastic constants of single crystals of orthorhombic S have been determined by the ultrasonic method. The values in units of 10^{11} dynes/cm² are:

$$\begin{aligned} C_{11} &= 2.40, & C_{22} &= 2.05, & C_{33} &= 4.83, & C_{44} &= 0.43, & C_{55} &= 0.87, & C_{66} &= 0.76, \\ C_{31} &= 1.59, & C_{23} &= 1.71, & C_{12} &= 1.33. \end{aligned}$$

AUTHOR.

2214. **The deformation and ageing of mild steel.**

W. SYLWESTROWICZ AND E. O. HALL. *Proc. Phys. Soc.*, 1951, **64**, 495.

2215. **A phenomenological theory of visco-elastic behaviour. I.**

D. TER HAAR. *Physica*, 1950, **16**, 719.

Recently, Sips [*J. Polymer Sci.*, 1950, **5**, 69] has studied the behaviour of visco-elastic substances, starting from a well-defined model, consisting of parallel Maxwell elements. The present series of paper applies Sips's method to a number of simplified models, and discusses for these models the relationship between various methods of measurement.

AUTHOR.

2216. **A phenomenological theory of visco-elastic behaviour. II.**

D. TER HAAR. *Physica*, 1950, **16**, 738.

The general theory (see preceding Abstr.) is applied to experimental results. The influence of the finite period of stretching prior to a relaxation or creep experiment and the physical meaning of the relaxation spectrum function $N(v)$ are discussed. An

approximate method for obtaining a rough impression of the relaxation spectrum from relaxation experiments is described and compared with the approximate method proposed by Alfrey. Relaxation spectra from experimental data of various authors are determined and various methods of exactly obtaining the relaxation spectrum compared. The yield value and the question of non-linear elements and the phenomenon of the glass-transition region are discussed. AUTHOR.

2217. A phenomenological theory of visco-elastic behaviour. III.

D. TER HAAR. *Physica*, 1950, **16**, 839.

The first two papers [Abstr. 2215-6] dealt with the behaviour of visco-elastic materials under static experiments. The present paper discusses periodic phenomena. At each frequency, the material otherwise described by a relaxation frequency spectrum $N(v)$ can be described by an equivalent Kelvin element, the modulus $E_1(\omega)$ and viscosity $\eta(\omega)$ of which are completely determined by $N(v)$ and depend on the frequency. It is also possible to give an equivalent Maxwell element. Various methods are described to determine from the complex modulus $E(\omega) [= E_1(\omega) + i\omega\eta(\omega)]$ the spectrum $N(v)$. The determination of $E_1(\omega)$ and $E_2(\omega) [= \omega\eta(\omega)]$ from the resonance curves observed in experiments with vibrating bars is discussed, and also the propagation of waves through a visco-elastic medium, a phenomenon which can be used to determine $E_1(\omega)$ and $E_2(\omega)$ for high frequencies. AUTHOR.

2218. Capacitance-change viscometer.

R. W. THICKENS. *Electronics*, 1951, **24**, 116.

A modified reversed Wagner-type cup-and-ball viscometer is employed in conjunction with an electrical timer which measures the interval between instants when the cup-fluid-ball separation is 0.005 and 0.003 in, the fluids under investigation being dielectrics. The cup-fluid-ball combination forms part of the tuning capacitance of a variable-frequency Hartley oscillator. This oscillator feeds two channels, each tuned to one of the two frequencies corresponding to the a/m spacings. The rectified outputs of the channels each charge a capacitor across the grid circuits of an Eccles-Jordan pair, in the anode circuits of which are relays controlling a 60 sec and a 6 000 sec clock. Thus resonance in one channel, corresponding to the 0.005 in spacing, starts the clocks and subsequently resonance in the other, corresponding to the 0.003 in spacing, stops them. Reproducibility within 1% is claimed. SCI. ABSTR.

2219. Precision measurement of Rockwell hardness diamond penetrators.

F. R. TOLMON AND J. G. WOOD. *Engineering*, 1951, **172** (4460), 89.

Methods of examining diamond penetrators for conformity with B.S. 891:1940 are described. Measurement of cone angles by means of a shadow protractor on the optically-projected image failed to give sufficient accuracy. Finally the supplement of the cone angle was measured in a horizontal plane by setting each flank in turn parallel with a datum plane formed by the semi-reflecting proof plane of an interference microscope. In this way an angular movement of 1' of arc was readily observable. The contour of the point was determined by projection to 1000 diameters magnification and comparison with a projection drawing; a departure of the profile from nominal by 0.001 mm could be observed. For more critical examination of the point, the use of a Zeiss "Linnik" interference microscope enabled the quality of finish of the surface to be observed and the general contour to be determined by examining the Newton's rings formed between the rounded point and an optical flat. V.G.W.H.

2220. A mechanical determination of biaxial residual stress in sheet materials.

R. G. TREUTING AND W. T. READ, Jr. *J. Appl. Phys.*, 1951, **22**, 130.

2221. Viscosity and density of aqueous lactic acid solutions.

R. A. TROUPE, W. L. ASPY AND P. R. SCHRODT. *Ind. & Eng. Chem.*, 1951, **43**, 1143.

Concentrations 10 — 85%. Temperatures 25 — 80°C.

2222. The measurement of viscosity. II. Measuring apparatus.

H. UMSTÄTTER. *Arch. tech. Messen*, Issue No. 179 (Ref. V9122-7) T136-T138 (Dec., 1950). *In German*.

Details of design of 12 instruments, classified according to the type of viscosity variation to be studied. These include viscometers depending on the observation of flow between parallel plane surfaces in relative motion, flow between rotating cylinders, and flow in different types of capillary, Philipoff's apparatus for observing longitudinal oscillations of a needle in a capillary filled with liquid, Höppler's consistometer and Umstätter's double-cone consistometer for measuring viscosities of 10^3 - 10^{10} poises, and falling-body viscometers suitable for measurements at high pressure up to 1 200 atm.

SCI. ABSTR.

2223. Note on the Hamel-Synge theorem.

F. H. VAN DEN DUNGEN. *Quatr. Appl. Maths.*, 1951, 9, 203.

The theorem given by Synge for a plane motion of a compressible viscous fluid is extended to three-dimensional motion.

2224. Optical methods of studying deformation (disturbed flow) of lubricants.

G. V. VINOGRADOV. *Doklady Akad. Nauk* (USSR) 1950, 71 (3), 505. *In Russian*.

Despite extensive study of flow kinetics of lubricants, little attention given to microstructure of flow and development of displacements or disturbance through heterogeneous stresses; conditions of reaching stationary and laminar systems unknown. Many calcium soap base (Solidol), sodium, lithium, and aluminium greases have sufficient transparency to permit optical study of layers from 1 to several mm thick, using methods known in hydromechanics. Flow of sodium grease past circular obstacle in capillary at rate of 10 to 30 cm/sec shown. Cine-film permits view of stationary and laminar systems under widely varying rates of deformation. Results in polarized light of particular interest. Russian greases thus examined gave new perspectives in rheology of dispersed systems. Optical methods, *eg* photo-elasticity and photo-viscosity, (a) permit control of macro-rheological methods, (b) can deal with cases not amenable to rheological methods, and (c) combine kinetics and dynamics of deformation processes with structure of systems. No additional substances or measuring devices needed.

Experiments show that many greases not homogenized after production have flow characteristics of disrupted gel. In polarized light, with low displacement stresses, seen that greases NK-30 or KV move in capillary column consisting of continuous or compact agglomerate of grains of varied dimensions (Fig 2 in original). With increasing displacement stress there is mutual intermovement of particles—mixing, frictional grinding etc. Conditions of stationary and laminar systems and their pseudo forms at higher rates of flow noted. Generally assumed distribution or mixing of grease in churn of penetrometer does not ensure effective homogenization: grease retains granular structure. Many rheological methods of determining properties unsatisfactory. Only by passing grease through very fine meshed sieve (size of order of 0.01 sq mm) is it made sufficiently homogeneous for usual macro-rheological test. Thus sample is shown (Fig 2) which only exhibits laminar "stationary" (steady?) flow already shown in Fig 1 of original after suitable homogenizing.

Results obtained with carefully homogenized greases, using flat or plane capillaries discussed. With lithium grease examined in polarized light, capillary was $1 \times 4 \times 100$ mm. Isochromatic method used, showing bands or streaks, and orientation of anisotropic submicro lines, for greases under various displacement stresses. Number of lines proportional to stress. Significance of movement, *eg* towards axis of flow, described, corresponding to distribution of zones of orientated particles and increase of displacement stress in that direction. Use of small quartz plate of sensitized colour and differently disposed in respect of axis of flow easily established meaning of bi-refraction phenomena in connection with flow of grease, and confirmed wider use of crystal-optical apparatus in this research. Case discussed of lubricant (Solidon) flow past or around obstacle in capillary (Fig 4 in original), where isochromes again indicate degree of orientation of soap particles, direction of which is shown by dark bands (isoclines) in white (plane-)

polarized light. Thus again easily possible to define different zones of orientated particles. Finally some phenomena related to transition from movement (flow) to rest considered. Significance of these factors in rheological study of dispersed systems summarized under 3 heads relating to optically sensitive dispersions, confirmation of earlier views on plastic flow by author, and to "frozen" (solidified) pictures of flow, well suited for defining stress release. I.D.I.B.

2225. The nature of tack.

A. VOET AND C. F. GEFFKEN. *Ind. & Eng. Chem.*, 1951, **43**, 1614.

A rolling cylinder tackmeter is described which will measure tack in absolute units at high speed of separation in liquid films between surfaces of a different nature. Particular attention is given to printing inks. As a result of experimental work it is concluded that tack in liquid films is related to a response to stress mechanism found in long chain molecules, characterized by a modulus of 10^6 to 10^8 dynes per sq cm and a relaxation time of the order of 10^{-4} seconds. Rapid film separation does not occur by liquid flow, nor is tackiness an essential attribute of every viscous liquid. It must be considered as a typical reaction of a freely moving long chain molecule to stresses of short duration. F.H.

2226. Dynamic study of reinforcement.

J. R. S. WARING. *Ind. & Eng. Chem.*, 1951, **43**, 352.

The measurements were undertaken to obtain a better understanding of the mechanism of the reinforcement of rubber by carbon black. Results are given for the dynamic compression modulus and its temperature and amplitude coefficients in the temperature range 30° to 70°C and at amplitudes of vibration around 0.0036 cm, for natural rubber, Neoprene type GN, GR-S, and Perbunan. Data are also given on the effect of vibration and temperature on electrical conductivity. The results are discussed in relation to the general level of reinforcement. Evidence is given for the rupture of more than one type of cohesive bond in repeated cycles of vibration. A tentative system of analysis is proposed. The different effects of temperature and continuous vibration on dynamic modulus are attributed to a thixotropic breakdown in the case of vibration. The significance of such a "structure", dynamically hard at small amplitudes of vibration, is related to abrasion of tyres in service. AUTHOR.

2227. The measurement of Young's modulus for ferrites.

L. WEIL AND L. BOCHIROL. *C.R. Acad. Sci., Paris*, 1951, **232**, 1807. *In French*.

Young's modulus for a mixed Ni/Zn ferrite has been determined by measuring the resonant frequency of radial oscillations in a ring. As the density of the specimen was less than the bulk density of the material it is expected that the value of Young's modulus found (1.17×10^{12} c.g.s.) is less than the true value. SCI. ABSTR.

2228. Stress temperature studies of transitions in rubbers.

R. S. WITTE AND R. L. ANTHONY. *J. Appl. Phys.*, 1951, **22**, 689.

2229. Fatigue fracture of steel.

T. YOKOBORI. *J. Phys. Soc. Japan*, 1951, **6**, 81.

Fatigue fracture of steel has been investigated, and the consideration developed here will in general hold for other metals. This line of thought may be applied to many other cases such as static fracture of brittle metals and yielding of polycrystalline metals. AUTHOR.

2230. Delayed fracture in creep of copper.

T. YOKOBORI. *J. Phys. Soc. Japan*, 1951, **6**, 78.

The fluctuation phenomena on the creep fracture in Cu were investigated experimentally. The observed fluctuations of time required for the occurrence of fracture after the application of load were analysed statistically, and it was shown that these creep fractures may be understood as a kind of rate process. AUTHOR.

2231. **Relaxation spectrum of glass.**

Y. L. YOUSEF AND R. KAMEL. *Nature*, 1951, 167, 945.

2232. **Tearline patterns in ferrochromium.**

C. A. ZAPFFE AND F. K. LANDGRAF. *J. Appl. Phys.*, 1950, 21, 1197 (letter).

2233. **Elastic modulus and swelling of Butyl vulcanizates.**

R. L. ZAPP AND E. GUTH. *Ind. & Eng. Chem.*, 1951, 43, 430.

BOOK REVIEW

Measurements of mind and matter.

by DR. G. W. SCOTT BLAIR. Pp. 116. (London: Dennis Dobson, Ltd., 1950). 9s.6d. net.

The immediate practical concern of rheology is with such concepts as the 'firmness' of a clay or the 'body' of a dough; these do not readily conform to the conventional methods of measurement, and are normally assessed by purely subjective judgment. Dr. Scott Blair is not satisfied with this rather 'unscientific' position of the rheologist, and has put forward a tentative scheme for widening the scope of physical measurements so that these rheological concepts may be assessed objectively. Although this book is primarily concerned with rheological problems, it may be interpreted in its broader aspects as yet another contribution to the ever increasing mass of literature dealing with the place of mathematics in scientific method. This problem—itsself intricately linked up with attempts to elaborate satisfactory definitions of science itself—has perhaps been stated in its most dogmatic form by Leonardo de Vinci.

Nessuna humana investigazione si puo dimandane vera scienza s'essa non passa per le matematiche dimostrazioni (no human enquiry can call itself a true science unless it proceeds by means of mathematical demonstrations).

No such dogmatic attitude is adopted in the present book; the author approaches the problem by a critical consideration of the physical basis of the theory of dimensions. The discussion falls naturally into two halves. The first five chapters are devoted to a consideration of the principles of measurements and the theory of dimensions. It is unfortunate that in these, much precision of thought,—with its consequent loss in the quality of the exposition,—has had to be sacrificed in the attempt to use only language and symbols which can be understood by that 'dimensionless' numeric, the intelligent layman, to whom the book is specifically addressed. This is particularly the case in Chapter II in which the imagery used to illustrate the nature of 'dimensions' is too naive.

The real argument of the book is unfolded in the remaining four chapters, in which the author introduces the idea of mental measurements and physiological dimensions and leads up to his theory of quasi-properties which he relates to Gestalt psychology. The treatment is full of interest, and, as one might expect from a person so mentally agile as Dr. Scott Blair, is presented in a provocative manner. A number of highly controversial points are raised, and dealt with by the author in critical vein in his attempt to break down the rigid barrier which would appear to separate physics and psychology. Essentially the book may be regarded as an eloquent plea against the attempted formalization of science—an attempt which would seem to be one aspect of the general tendency to impose, in circumstances that often do not warrant it, a unitary view in the borderline sciences. Every true scientist must be endowed with an adventuresome spirit, because in science there always has been, and presumably always will be, the need for speculation. This volume is a good example of his spirit, and therein lies its real value.

A. E. A. WERNER.