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BRITISH RHEOLOGISTS' CLUB

Address for communications:

c/o The National Institute
for Research in Dairy-
ing, Shinfield, Reading

Circular No.7

March, 1944

Issued for the information
of members of the Club
only

Membership

The membership figure now stands at almost exactly 200. The steady growth of the Club is most encouraging.

Meetings

1. Didsbury, Saturday, April 29th.

A meeting will be held on Saturday, April 29th, 1944 at the Shirley Institute, Didsbury, Manchester, the laboratories of the British Cotton Industry Research Association, at the invitation of the Director, Dr.F.C.Toy.

The subject for discussion at the meeting will be:-

"The Elastic Behaviour of Textile Materials".

It is proposed to hold a meeting in the morning, starting at 10 o'clock, at which several short papers will be read. The following have undertaken to contribute papers to this discussion:-

Dr.F.T.Peirce (British Cotton Industry Research Association) "Elastic After-Effects in Textile Fibres"

Messrs Berry and Entwistle (Courtaulds Ltd) "Some Rheological Properties of Highly Oriented Viscose Rayons"

Prof.J.B.Speakman (Leeds University) (Title to be announced later)

Messrs R.C.Seymour and J.M.Buist (I.C.I.(Dyestuffs)Ltd.) "The Visco-Elastic Properties of Nylon"

Mr.R.S.Higginbotham (British Cotton Research Association) "The Effect of Chemical Modification on the Rheological Properties of Starches"

The authors have been asked to make their papers sufficiently short to allow time for a discussion. It is hoped to send abstracts of the papers in advance to those proposing to attend the meeting.

Lunch will be served at the Institute from 1 to 2 p.m. price 3/6d

In the afternoon, from 2 to approximately 4 o'clock, the laboratories of the Institute will be open for inspection and there will be a series of exhibits relating to rheological and other subjects (Including the Electron Microscope).

Accommodation at the meeting is limited by the size of the Institute's library and dining room to approximately 80. Members wishing to attend the meeting are asked to fill in the slip attached to this Bulletin and to indicate if they wish to bring guests. The slip should be returned to Dr.W.A.Richardson, Shirley Institute, Didsbury, Manchester, 20. not later than Saturday, April 8th.

Transport

The Shirley Institute is reached by the Gatley (No.1), East Didsbury, (No.1X), Stockport (No.74), Wilmslow & Alderley Edge (No.52), and Wilmslow and Macclesfield bus services from the Piccadilly Bus Station, Manchester. The services are fairly frequent, and the journey takes about 30 minutes.

Return to Manchester after the meeting

If a sufficient number of visitors signify their intention to

return to Manchester in time to catch the 5.30 train to London a special bus can be arranged to leave the Institute at about 4.30.

Hotels in Manchester

The Queen's Hotel, Portland Street and the Grand Hotel, Aytoun Street are both near London Road L.M.S. Station and the Piccadilly Bus Station. The Midland Hotel is close to the Central Station. Some rooms have been provisionally reserved at these hotels for the night of Friday April 28th. The local organiser will be pleased to assist members who have difficulty in obtaining hotel accommodation.

2. Rheology weekend

War conditions permitting it is intended to hold a weekend Conference in Oxford from July 6th - 9th. Accommodation with full board will be available at a cost of approximately 36/- per person at St.Hilda's College where the meetings will be held. Members are invited to bring friends whether rheologists or not. Those unable to stay for the whole weekend are welcome for any part of the time and will be charged accordingly. There is no registration fee.

The provisional programme includes discussions on "Rheology of large deformations and plastic flow (a) metals (b) high polymers (c) liquids". "Relation between shear, tension and compression in complex bodies".* "Some rheological applications to medical science". "Rheological nomenclature and symbols, metallurgical and non-metallurgical". "Future organisation of rheology". It is hoped also to visit laboratories of rheological interest. Short summaries of contributions to these discussions may be sent to the Hon.Secretary not later than June 1st for pre-circulation to those who hope to attend.

The Hon.Secretary realises how difficult it may be for members to make definite plans in advance at this time but they too will appreciate the difficulty of planning a Conference unless the fullest possible information is available. Will members please inform the Hon.Secretary as soon as possible whether it is probable or possible that they will attend all or part of the Conference and giving some indication as to the probable number of guests? It is fully realised that no one can be bound by promises to attend and plans may have to be altered as the situation develops but the Committee feels that there is a good chance that a very helpful meeting may be held and asks members to co-operate by keeping the Hon.Secretary as well posted as possible as to their intentions. Further details will be circulated later.

Rheology Abstracts

Note: The Club assumes no responsibility for the opinions expressed by abstractors; these are given in square brackets.

175. A New Recording Viscometer for Paint Consistency Measurements.

C.R.Wicker & J.A.Geddes. A.S.T.M. Bulletin. No.120. p.11. January, 1943. This article describes a rotation viscometer, the outer cylinder being rotated at two sets of four speeds (100, 140, 200 and 285 r.p.m. or 30, 42, 60 and 80 r.p.m.). The couple on a modified Stormer type paddle is balanced by a spring provided with an inking mechanism drawing a continuous line on a moving chart. Calibrated by a Stormer viscometer at one speed the relations obtained agree at all speeds. The behaviour of thixotropic and rheopectic materials is illustrated as well as the effects of bodying oils and thinners. Lack of temperature control, kinetic energy corrections and other sources of error are discussed by Bingham and others. L.B.

176. Flow Properties of Coating Clays at High Rates of Shear. Kenneth

A. Arnold. Paper Trade Journal. 117. pp.28-34. 1943. A process has been developed for measuring the flow properties of coating clay slips at rates of shear in the range of 8.0×10^4 reciprocal seconds, which is in the range of shear produced in high speed coating machines. During the measurement the slip is also subjected to pressures com-

* See Report on p.13 of this Bulletin.

parable to those in the actual coating nip. The procedure distinguishes between the Newtonian, dilatant and thixotropic types of fluid flow and indicates the behaviour of slips possessing these types of flow in a roll nip. A method is presented for the quantitative determination of the degree of dilatancy and thixotropy of clay slips. This method does not destroy the structure of the clay system previous to the actual measurement of its flow properties.

At high rates of shear, the nip viscosity of clay slips was found to be critically dependent upon the clay concentration, especially at very high solids contents. The concentrations of three commercial paper coating clays required to produce slips of equal nip viscosity were found to differ widely. Extremely dilatant slips were produced from the two clays of lower hydration capacity, although one of these showed a small particle size. No degree of dilatancy could be attained in slips of the more highly hydrated clay, although it possessed the larger particle size. With these clays the range of dispersing agent required to give minimum viscosity to the slips was found to increase as the concentration of clay was increased. In general, the flow properties of clay slips were found to change considerably with the amount of mechanical work to which they were subjected.

The results of nip viscosity measurements showed very little correlation with low-shear viscosity measurements in the MacMichael viscometer. Furthermore, certain slips which showed weakly dilatant behaviour at low rates of shear, according to Sheets, were actually thixotropic under high shear. By a careful selection of the amount of work applied, the amount of dispersing agent used and the concentration of the clay, it was possible to prepare slips from different clays which showed very similar flow properties.

The method makes use of a cylinder rolling down an inclined plane.
V.G.W.H.

(Abstracts Nos.177-205 inclusive contributed by the British Refractories Research Association).

177. On the Theory of Finite Deformations of Elastic Crystals. R.Furth. Proc.Roy.Soc., Ser.A,180, 285 1942. The general theory of finite deformation of cubic crystals at zero temp. is developed to a 2nd order approximation. Certain special cases are worked out in detail.

178. The Softening of Thermoplastic Polymers. 1.Theoretical. R.F.Tuckett Trans.Farad.Soc. 39, 158, 1943. The general deformation produced in an amorphous high polymeric material by a given stress is analysed into its three components which are termed ordinary elastic, highly elastic and viscous. These all have different dependencies on molecular size, structure, temp. and duration of stress - the effect of these variables is worked out and the information obtained is used to analyse the various empirical softening point tests which are in current use to characterise plastics. It is shown that such tests fall into two main groups: (1) those which measure the flow properties of materials and, as such, are of use in evaluating correct moulding conditions. (2) the second class essentially measures the temp. at which high elasticity develops - this is important in assessing heat distortion properties of the material under working conditions.

179. Classification of Rheological Properties E. Bartlett. Nature, 151, 198, 1943. The writer suggests that the classification previously put forward would be clearer if deformation were divided into three types: plastic, elastic and viscous. The sub-divisions of these types are illustrated in a 'family tree'.

180. Rheological Series R.H.S. Robertson and H.W.J. Hathaway. Nature 151, 728, 1943. The rheological behaviour of a mixture of 10 gm. fullers' earth with 170 gm. Na silicate soln. is described. It is suggested that rheological series of this kind may be useful in testing the validity of 2- or 3-dimensional diagrams designed to show the relationship between the various rheological phenomena.

181. Fluid Flow through Porous Media. I. N.C.Sengupta and M.T.Nyun. Indian J.Phys., 16, Pt.2, 119, 1942. The rate of flow of H_2 and O_2 at various pressure gradients through two cores, one of high permeability, was studied. The permeability calculated from the data for the core of lower permeability was more or less constant up to the highest pressure gradient studied, namely, 0.39 atm./cm. with H_2 and 0.45 atm./cm. with O_2 . With the other core the permeability appeared to decrease with increase in the pressure gradient. This decrease could not be accounted for by a turbulence effect, since the Reynolds no. was in all cases considerably below unity. For both cores, permeabilities calculated using data from the rate of flow of O_2 were less than those obtained from similar calculations with H_2 . This appeared to be due to slip effect and the true permeabilities obtained after correction for slip were less than the observed permeabilities obtained by direct measurement with gases. II. Ibid. 17, Pt.1. 39, 1943. Permeabilities, porosities and particle size distribution curves of 23 sand core samples were obtained. It was observed that with increase in the average particle diam. the porosity at first increased and then tended to attain a constant limiting value. The permeability, on the other hand, increased continuously with the average diam.

182. Anomalous Flow in Glasses. N.W.Taylor. J.Phys.Chem. 47, 235, 1943. Glass is a material having properties very dependent on thermal history. Viscosity and elasticity are properties very sensitive to structure, consequently their study provides an insight into the nature of glasses. The dissociated character of glasses at high temp. tends to be preserved on quick cooling, owing to the high viscosities but as association proceeds the glass finally becomes stabilised. Such a glass shows a viscosity which at constant temp. is constant, i.e. independent of time. The rate of association appears to follow a bimolecular reaction law, e.g. the rate of stress release is proportional to the square of the stress. When stabilised glass is subjected to a constant stress, the elongation is a summation of elastic adjustment and viscous flow. The former is itself complex, being a combination of several relaxation processes of different characteristic rates and of opposite sign, and gives rise to anomalous reversals. Examples of such phenomena in the discharge current of condensers and in the ageing of thermometers are described. A "molecular" picture of a glass based upon the above mentioned properties is presented.

183. On Anomalies of Elasticity and Flow and their Interpretation. R.Sinha. J.Phys.Chem. 47, 348, 1943. Elastic relaxation, elastic after-effect and creep, characteristic for inorganic glasses and high polymers, are considered. The behaviour of such materials is characterised by the existence of a whole set of a distribution or mechanical relaxation frequencies. Similar conclusions have been reached on the basis of the dielectric dispersion of polar polymers. Three molecular mechanisms, determine roughly the relaxation spectrum of a high polymer: The reaction of the chain segments to the applied stress; the change of shape of the chain as a whole; and the mutual interaction of chains. It is shown how the Boltzmann memory function and the spectrum may be obtained by creep data.

184. Measurement of Anomalous Viscosity by the Capillary Tube Method A.C.Merrington. Nature. 152, 214, 1943. Errors arise in capillary viscometers of the Bingham and Ostwald types when used with anomalous liquids, since the rate of shear in the vessel is much lower than in the capillary. The magnitude of the error depends on the relative dimensions of the apparatus and the form of the viscosity/shear curves. It has variously been attributed to thixotropy or to the assumption that the streamlining layers are not infinitely thin. The viscosity/shear curve is independent of the capillary if the capillary is sufficiently long.

185. The Roll of Moisture in Soil Mechanics R.K.Schofield. Chem.Ind. 62, 339, 1943. The relation of base exchange to the movement of water to clay is discussed. Flocculated clay settles as flocs

and water
flocs

and water can readily move through the large pores thus formed; deflocculated clay, on the other hand, settles slowly as independent particles to form a compact mass through which water can move only with difficulty.

186. Soil Mechanics: The Factor of Safety of Clay Banks. E.C.Smith. J.Inst.Civil Eng. 18, 293, 1942. An extension of the ϕ - circle method of investigating the stability of a clay bank is outlined.

187. Research on the Consolidation of Clays. D.W. Taylor. Massachusetts Inst.Tech.Ser. 82, Aug.1942. After a preliminary survey of present theories on the consolidation of clays, fundamental research carried out during the years 1935-39 is described. This included studies of side friction, consolidation under gradual application of load, and effect of loading increment on consolidation characteristics and pore pressures during consolidation. Hypotheses are put forward to account for secondary compressions and plastic resistance to compression. It is necessary to recognise two types of bond: the first type depends only on the amount of secondary compression while the second type is due to the cementation or inter-attraction of clay grains which attends the undisturbed strength of clay in nature. The "bond" is defined as the plastic resistance existing at the termination of primary compression; however, a part of the resistance thus designated as bond is in reality a slow viscous resistance.

188. Colloid Chemistry in Ceramics. A.L.Johnson. J.Amer.Ceram.Soc. 26, 88, 1943. The mechanism underlying the plasticity of clay is discussed from the standpoint of the forces in the lyosphere. If the resultant force is one of repulsion between micellae, the clay will more easily be deformed and more readily ruptured than will a clay having attraction forces at the edge of the lyosphere. Further study of this branch of colloid chemistry should lead to greater control of the plastic properties of clays and other materials. The colloid chemistry of the base exchange processes in clays has a direct bearing on the casting of clay products; the subject receives brief discussion.

189. Plasticity and Workability of Ball Clays. E.C.Henry. Bull.Amer.Ceram.Soc. 21, 269, 1942. Methods for measuring the flow properties of ball clays in the plastic state are compared. The concepts of "workability" of interest to ceramists include (1) plastic flow properties (yield value and mobility), (2) adhesiveness (stickiness), and (3) cohesiveness (the ability to be deformed without rupturing). Ball clays probably influence the workability of white-ware body chiefly by making it cohesive.

190. Water of Plasticity. J.W.Whittemore. Bull.Amer.Ceram.Soc. 21, 268, 1942. The American Ceramic Society Method for determining the water of plasticity, and the A.S.T.M. method for the liquid limit of soils are described. It is suggested that the methods might be more fully mechanised, and that the conditions under which the test pieces are made might be more closely controlled.

191. Control Testing for Consistency of Refractory Mortars. E.C.Petrie and D.W.Kocker. J.Amer.Ceram.Soc. 25, 459, 1942. Various methods for determining the consistency of mortars are discussed, and data are included to show the test results obtained using different instruments. A description is given of a modified Vicat needle which may be used for the control of consistency during the manufacture of wet-type, cold setting mortars.

192. Evaluation of Plastic Properties of Clay Masses. R.Russell. Bull.Amer.Ceram.Soc. 21, 271, 1942. The factors involved in the evaluation of plastic properties of clay masses are discussed. Some of the commonly used methods of testing the plastic character of clays are described, and several adaptations of tests often used on clays are proposed for consideration.

193. Measurement of Workability of Ceramic Bodies for Plastic Moulding Processes. E.C.Henry. J.Amer.Ceram.Soc. 26, 37, 1943. The plastic working properties of a number of clays and bodies were measured with a modified Endell body tester. The apparatus shows that various bodies may be adjusted to a similar consistency for a given moulding process, but differ in their tendency to crack on being deformed. It is possible to determine the extent to which plastic properties are affected by differences in raw materials, methods of body preparation, water content, ageing and de-airing.
194. Simple Apparatus for Studying Deformation of Soft Materials Under Compression and Tension at Constant Stress. G.W.Scott Blair and B. Veinoglo. J.Sci.Instr. 20, 58, 1943. Apparatus is described for extending cylinders or strips and also for compressing cylinders in such a way that the load per unit of average cross section remains adequately constant for big strains. This compensation in the loading is achieved by a weighted lever, the moment varying as the cylinder is compressed. The conditions under which this compensation is satisfactory are determined by experiment. The accuracy is adequate for most industrial rheological measurements for materials soft enough to be considered as incompressible.
195. Methods of Testing the Consistency of Refractory Mortars and Coatings. R.R.Matveyev. Ogneupory. 9, 110, 1941. D.A.Abram's cone method and W.M.Cohn's loaded sphere method have been tested on grog clay and grog cement mortars. In the cone method, a mould in the form of a truncated cone is inverted on a flat surface and filled with the mortar. It is then lifted vertically and the amount of subsidence of the slumped specimen gives a measure of the consistency. A conical mould 10 cm. high, 9.9 cm. base diam. and 6.6 cm. diam. at the open end was used by the author and gave consistent results. An improved form of Cohn's apparatus is described, in which a sphere of 5 cm. diam. is forced through the material under a constantly increasing load. The consistency may be defined by (1) the "critical load" i.e. the min.load causing free movement of the sphere through the material, or (2) the load required to produce a given penetration. The cone test is simple and gives sufficiently accurate results with materials of normal consistency. The loaded sphere method may be applied to a wider range of consistencies, but is not suitable for grog-cement mixtures.
196. Theory and Measurement of Plasticity and Workability of Mortars. P.S.Roller. Proc.A.S.T.M. 42, 750, 1942. The plasticity of mortars is measured on the basis of a stress strain relation that previously had been formulated and applied to various dispersions. Two constants are determined, coefficient of plasticity, π , and yield value, P_0 only the latter depending on the mixing water content. Plasticity is defined in terms of ease of deformation and interpreted as one of the factors of workability of which four are discussed. The other three factors are: tendency to rupture during plastic flow, tendency to suspension of plastic flow, and water retention. π is shown to determine plasticity, and to be a good measure of overall workability. Water retention, as one of the factors of workability, was measured directly and with P_0 at 16.7% mixing water as an index. It was found to be well correlated with π for a series of 1 : 3 mortars of portland cement with added mineral powders. Relative to these materials at the same plasticity the water retention of 1 : 3 mortars of several masonry cements and a slag cement seemed to be low. Theoretical factors involved in plasticity and workability are discussed.
197. A Critical Analysis of Stokes' Law as a Basis for the Determination of Particle size of Clays and Nonplastic Materials. R.M.King. Bull.Amer.Ceram.Soc. 21, 258, 1942. Objectives desired in particle size determination are examined. The influence of preparatory treatment of the clay sample on the distribution of particle size is reviewed. The errors and limitations of Stokes'

law are considered, particularly with respect to the correct value for the density of the suspended material. Recent developments in the colloidal chemistry of clays are used as a basis for this discussion.

198. Flow Measurement. British Standards Institution. B.S. 1042, 1943.

The conditions governing the design, installation and use of standard pressure-difference devices in order to obtain consistent results, within a specified tolerance, from commercial instruments are considered. Nozzle, orifice plate and Venturi instruments are dealt with.

199. The Rolling Ball Viscometer. R.M. Hubbard and G.G. Brown. Ind. Eng. Chem. Anal. Ed. 15, 212, 1943. A study of the system of the inclined tube and rolling ball as applied to the measurement of viscosity is described. Dimensional analysis was used to derive general relations between the variables involved and the simple calibration for the rolling ball viscometer in the streamline region of fluid flow. The coefficient of the calibration equation may be calculated from the dimensions of the instrument with the aid of an experimentally determined empirical factor. By using the equations given, the useful range of the rolling ball viscometer may be predicted without experimental calibration, or an instrument may be designed for measurements over any desired range of viscosity. An empirical correlation is given which allows viscosity to be estimated from data taken on the viscometer in the turbulent region of fluid flow. The effect of temp. changes on the viscometer and its calibration is discussed.

200. A Method of Viscosity Measurement in the Region 10^8 Poises.

S.M. Cox. J. Sci. Instr. 20, 113, 1943. A simple method of measuring the viscosity by spherical imprint is described, particularly in connection with the viscosities of glasses in their softening range. A formula gives the viscosity in terms of the radius of imprint, the compressive force, the time and the radius of the sphere.

201. The Viscosity and Working Characteristics of Glasses. I. The Viscosity of some Commercial Glasses at Temperatures between approximately 500 and 1,400°C J. Boov and W.E.S. Turner. J. Soc. Glass Tech. 26, 215, 1942.

As the preliminary to a systematic review of the relationships between the viscosity of a mass of glass (or, more strictly, between the viscosity at different points of the mass) undergoing manipulation by hand or machine, and the temp. ranges between which the various stages of manipulation can be satisfactorily carried out, the viscosities of 24 glasses, 3 of them synthesised from pure materials and 21 of different types employed commercially, have been determined by two precision methods. The Margules method was used for temps. from approximately 750° to 1,400°C and a fibre extension method for temps. from approximately 500° to 800°C. From the results, combined with such trustworthy data as have been obtained by other workers, factors have been derived for the oxides SiO_2 , Al_2O_3 , Fe_2O_3 , CaO , MgO , Na_2O , and PbO by which, within prescribed limits of composition, the viscosities of glasses containing them can be calculated.

202. The Viscosity and Working Properties of Glasses. II. The Rate of Cooling and Setting of Colourless and Coloured Glasses. J. Boov. J. Soc. Glass Tech. 27, 94, 1943.

A comprehensive study of the rate of cooling of glasses contained within a crucible was made. The glasses tested comprised 5 commercial types, colourless and coloured, based on a soda-lime-silica composition, 2 colourless alkali-lead oxide glasses, a high softening pt. boro-aluminosilicate, and a soda-silica glass. In addition, 8 glasses coloured blue by CoO , present in varying concentrations up to 5% were studied. Determinations were made by Pt./Pt. Rh thermocouples of the temps. at the glass surface and at intermediate pts. within the interior when the crucible and the glass within it were cooling under two different sets of conditions.

From the temps. recorded at different times of cooling the corresponding viscosities were deduced. The temp. differences between the surface and interior of a mass of glass during cooling depend on the time during which the cooling has proceeded; on the initial temp. from which cooling begins; and on the composition of the glass, particularly the presence of colouring constituents. As regards the effect of time, the difference in temp. between surface and interior increases rapidly to a max. during the early stages of cooling and then slowly decreases to zero as the glass cools uniformly to room temp. The relative times required for the soda-lime-silica glass to cool through the first 400°C from the different initial temps. are given for the surface and for a pt. 0.8 in. below the surface. These data apply to conditions described, in which the crucible and glass cooled slowly in an insulated chamber. Data are given in the paper for other glasses and other temp. ranges and conditions. The differences in temp. between surface and interior were markedly greater in the coloured than the colourless glasses, partly due to the greater emissivity of the former and partly due to the selective absorption they exercise, resulting in the longer retention of heat in the interior during the cooling process. The temps. are given for a colourless soda-lime-silica glass, a carbon-sulphur amber glass, a cobalt blue glass and an iron-manganese green glass, when cooling from an initial temp. of 1400°C at the surface and 0.8 in. below the surface. In coloured glasses the temp. differences between surface and interior are very marked within a narrow layer at the surface. The rate of setting of a glass is influenced by the temp. coefficient of viscosity and by the initial temp. from which cooling begins and the composition, particularly the presence of colouring constituents. Tables and graphs show in detail the effects of all three factors. The very marked differences of temp. within the first 0.1 inch of the surface layer in the case of coloured glasses gives rise to correspondingly big viscosity differences resulting in a "skin" effect which governs subsequent manipulative operations.

203. Analysis of the Thixotropy of Pigment-Vehicle Suspensions.

H. Green and R.N. Weltmann. Ind.Eng.Chem.Anal.Ed. 15, 201, 1943. The meaning of thixotropy is first considered and the use of the hysteresis loop for the evaluation of thixotropy is discussed. This loop is obtained by plotting the torque against the speed of rotation of a viscometer, when the latter is first increased and subsequently reduced. The loop indicates breakdown of colloidal aggregates as the speed of rotation is increased, with subsequent re-coagulation as the viscometer is again brought to rest. Some mathematical features of the thixotropy loop are discussed.

204. Thixotropic Behaviour of Oils. R.N.Weltmann. Ind.Eng.Chem.Anal. Ed. 15, 424, 1943. Various types of oils in the viscosity range

of 1 to 800 poises were measured on a rotational viscometer capable of imparting shearing stresses over a wide range. From these oils, flow curves were obtained extending from low to high rates of shear. All these oils showed a definite thixotropic behaviour and exhibited all the characteristics of thixotropic plastics above a certain rate of shear designated as "the limiting rate of shear". Below this critical point the oils behaved like true Newtonian liquids, showing no signs of thixotropic structure. The limiting rates of shear were found to be related to the measured true Newtonian viscosities of the oils. The product of limiting rate of shear and viscosity was a constant for all the oils tested.

205. Apparatus for Measuring Thixotropy. F.W.Goodwin and M.H.Heeren.

U.S.P., 2,303, 162, 24.11.42. The sample is placed in a cup into which dips an open-ended cylindrical rotor, suspended by a torsion wire. A torsional force is applied to the wire and mechanism indicates the initial movement of the rotor.

206. The Physical Properties of Paint Systems. H.W.Rudd. Paint

Manufacture. 13, 264, 296, 1943. 14, 20, 1944. The phenomena generally associated with pigment/vehicle suspensions are reviewed under the following heads: wetting and dispersion; the contact

angle; sedimentation, flocculation, thixotropy and false body; the effect of small amounts of water in inducing thixotropy. Conventional methods used in attempting to eliminate paint defects related to the above are described and the mechanisms of the various processes are discussed.

J.E.A.

207. Structure and Physical Properties of Plastics Part II. L.W.

Turner. J.Soc.Chem.Ind. 62, 492, 1943. The author discusses methods of measurement of deformation as a function of time, over a temperature range. No new experimental evidence is presented but several new and interesting points are made. A continuous distribution of relaxation times is assumed and it is stated that

- (a) increase of temperature narrows the distribution
- (b) increasing plasticization broadens it
- (c) the more crystalline polymers possess the broadest distributions of relaxation times.

R.C.S.

208. Boiling Point and Viscosity of Gases. A. Dutta. Nature. 152, 445,

1943. From measurements of the compressibility of liquids and liquid mixtures, a connection between viscosity (η) and compressibility (β) has been suggested

$$\eta = A T^{\frac{1}{2}} e^{B/\beta}$$

A further equation

$$\eta/\eta_{\beta} = x e^{\frac{1}{x} - \frac{1}{x_0}} \quad \text{where } x = \left(\frac{T}{T_0}\right)^{\frac{1}{2}}$$

involving the boiling point temperature (T_B) and the viscosity of the gas (η_{β}) at T_B has been found to hold for air, argon, hydrogen, nitrogen, oxygen, CO_1 , CO_2 and for the vapours of C_6H_6 , $CHCl_3$, CCl_4 , CS_2 etc.

R.C.S.

209. The Properties of Liquid Sulphur R.E.Powell and H. Eyring. J.

Am.Chem.Soc. 65, 648, 1943. The transition-state theory of viscous flow is applied together with quantitative thermodynamic theory to the available measurements of the equilibrium between 8-membered sulphur rings and sulphur chains of all lengths. Using the values of molecular composition computed in this way, the viscosity is formulated in terms of current theories, and calculated and experimental values are compared.

R.C.S.

210. The Fundamental Problem of the Theory of Viscous Fluids. H.

Putman. J.App.Phys. 14, 244, 1943. A mathematical theorem is proved giving the value of $\frac{d(\nabla \cdot \vec{v})}{dt}$ for viscous fluids. With the

known value of $\frac{d\vec{\omega}}{dt}$ this gives a useful theoretical method of studying the fundamental problems of viscous fluids.

R.C.S.

211. The Annealing of Glass. W.A. Weyl and A.G.Pincus. J.App.Phys.

14, 37, 1943. The rate of removal of mechanical strain should follow Maxwell's first order law, but for glasses, it is found that the rate is proportional to the square of the birefringence. During annealing, the stress optical coefficient of glass as well as its viscosity undergoes a continuous change, and these authors conclude that birefringence is not a correct measure of stress.

R.C.S.

212. Flow and Recovery Properties of Viscose Rayon. J.J.Press. J. App.

Phys. 14, 224, 1943. A series of flow and recovery measurements are used as a basis for the description of the elastic, viscous and tensile properties of viscose rayon. Extensions of this material at $70^\circ F$ and 65% R.H. are given, under loads of 0.1 to 1.0 gms/denier (1900 - 19000 lbs/in²) for times up to 10^6 seconds.

The data are interpreted in terms of changes in modulus, viscosity

restoring forces, crystallization and internal load distribution.
 [This paper contains an excellent bibliography on the rheological properties of textile materials.] R.C.S.

213. Evaluation of Rheological Constants from Tensile and Compressive Tests W. Lethersich, J.Sci.Inst. 21, 27, 1944. A formula is derived from which the tensile stress in compression or extension can be related to the shearing stress. For large strains Poisson's ratio (π) is defined as the ratio of the logarithmic lateral strain to the logarithmic longitudinal strain. If Poisson's ratio is 0.5 (for incompressible materials) the correction to be made for the change of stress due to change in cross-section consists simply of calculating the strain on the final length. R.C.S.

214. Strömungsoptische und Viskometrische Untersuchungen über den Lösungszustand von Casein (Investigations on the solution conditions of Casein by Viscometry and by optical Tests on the Flowing Material). H. Nitschmann and H. Guggisberg. Helv.Chim.Acta. 24, 574, 1941. This is the second of a series of papers on this subject. The authors are mainly concerned with establishing how far the deviations from Emstern's formula for sodium caseinate and various salt solutions are due to electroviscous effect, voluminosity and anisotropy respectively. They conclude that the last is the preponderant factor and derive anisotropy ratios from the formulæ of Burgess and Polson, generally getting twice as much anisotropy from the former as from the latter. Undeterred, they continue to speculate on the structure of the casein particles. After a short diversion to discuss similar problems for tobacco mosaic virus and egg white protein, they return to the attack, concluding with a study of the effects of alcohol and acetone on the already complex phenomena described for casein. There is no summary.

[One might guess that this paper formed some kind of thesis which might profitably have been re-written in a much shorter and more orderly fashion before publication.] G.W.S.B.

215. High Elastic Deformation of Polymers. B.J.Brajnukoff. "Plastics". 7, 79, 572, and 8, 80, 44-50. These papers contain a very helpful discussion on the modern theory of high elasticity. They also give an informative account of some of the recent experimental work carried out on the mechanical properties of polymeric materials. Much of the work and ideas of Meyer, Kuhn, Mark and of Alexandroff and Lazurkin is summarised. The formula

$$D = D_{el} + D_{elo} = \frac{1}{E_{el}} + \frac{1}{E_{elo}} = 1/E$$

is stated to govern the deformation of a body which is "balanced at a given force" where D , D_{elo} , and D_{el} signify values which are reciprocal to the corresponding moduli and are proportional to the relative deformations. E , E_{el} , E_{elo} , are respectively the total modulus, Young's modulus, and modulus of High Elasticity. It is further stated that E_{elo} is proportional to the absolute temperature (T). The general equation of Alexandroff and Lazurkin

$$D = D_{el} + D_{elo} \left(1 - e^{-\frac{tK}{T}}\right)$$

for total deformation is also included and the dependence of this deformation on temperature and time of application of the deforming force is shown graphically. Actual polymers are shown to follow this law very closely.

216. Structure and Physical Properties of Plastics. Pt.1. Theoretical R.F.Tuckett. Chemistry and Industry. 430-432, Nov.1943. Pt. 2 Experimental. L.W. Turner. Chemistry and Industry. pp.492-494, Dec.1943. (a) The first paper contains a very lucid account of the correlating between the more common mechanical tests applied to plastics and their structure. Three types of deformation which can occur when a stress is applied to a plastic are (a) an instantaneous deformation due to a

change in the inter-atomic or chain-chain distances (b) one arising from a change in the distance between the ends of the molecular chains (c) a deformation due to the chains sliding over each other; and they are denoted respectively by D_{oe} , D_{he} , D_{vis} . D_{oe} is immediately recoverable on removal of the stress and is practically independent of temperature; D_{he} is dependent on temperature, takes a finite time to complete and also to disappear on removal of stress; D_{vis} is completely irreversible. The relationship between these three types of deformation and various mechanical and softening point tests for plastics are discussed.

(b) An equation is given in the second paper relating deformation (D), stress (S) and time (t) of application of stress.

$$D = S/G_{oe} + S/G_{he} (1 - e^{-t/T}) + St/\eta$$

where T is orientation time.

Methods of test are discussed in some detail under the three headings, Static Methods, Dynamic Methods, and Viscometric Methods; and some tests results on actual plastic materials are included. The importance of adequate temperature control of test specimens is emphasised.

W.G.W.

Book Reviews

Elastic and Creep Properties of Filamentous Materials and other High Polymers. H. Leaderman. The Textile Foundation, Washington D.C. 1943.

This book consists of two parts. In the first part, the author gives a historical survey of early work on elastic fore- and after effects and similar phenomena which he defines as "primary creep". The papers of Weber, R. & F. Kohlrausch, Boltzmann, Hopkinson, etc., which are not easily accessible, are fully summarised, the centre of the picture being taken by the Superposition Principle. In the second chapter, Wiechert and Maxwell's theories are fully discussed in terms of spring and dashpot models and Chapter III gives a brief history of studies on the structure of high polymers.

The second part of the book consists of a description of the author's experiments with a "creep balance" mainly on silk, acetate rayon and nylon fibres, the effects of temperature and relative humidity being especially discussed. In spite of many complexities, the applicability of the Superposition Principle (in slightly modified form) is remarkably wide.

[This is a most valuable addition to the rapidly growing rheological literature. Were the work less worth while, the rather obscure style would not justify mention; but it is an unfortunate fact that the very valuable summary of early work is often hard to follow. Moreover the use of the same symbols to describe widely different experimental conditions is distracting in spite of theoretical justification from the Principle of Superposition; and the multiplicity of constants such as the two exponents ($m = 1 - n$) and the other constants ($a = 1/1 - n$) does not make for clarity. The bibliography of early papers is most valuable but that for more recent times might profitably be augmented.. Equation 5 on p.13 appears to be in error.]

G.W.S.B.

Ten Lectures on Theoretical Rheology Markus Reiner. Rubin Mass, Jerusalem.

The book contains ten lectures, amplified by notes, delivered at Jerusalem and is the forerunner of an elementary introduction to theoretical rheology. The first lecture is devoted to the analysis of a general strain (which is expressed in tensor notation) of a body. By expression the stress in a body in tensor form, the rheological equation of state $R(e, p) = 0$ is found (lecture 2) where e , p , are the strain and stress tensors and R is called the rheological function. The special case $e = 0$ is the ideal rigid body

which cannot be strained (Euclid solid). At the other extreme is the incompressible ideal liquid (Pascalian liquid) for which the stress tensor reduces to a uniform hydrostatic pressure. All real bodies lie between these extremes.

The next simple case follows from the resolution of a tensor (without change of form) into a dilation and a deviator (lecture 3). A simple proportionality between stress and strain, for the two components independently, gives the ideal elastic body (Hookean solid). The usual relationships between bulk, rigidity and Young's moduli and Poisson's ratio are deduced. Replacing shear modulus by viscosity and strain by rate of strain, in the rheological equation of the ideal elastic body, the equation for the Newtonian fluid follows. The co-efficient of viscous traction measured by a simple pull (in the absence of bulk viscosity) is three times the viscosity. This fourth lecture thus sets up the equations of the classical bodies; between the Hookean solid and Newtonian liquid lie the "rheological bodies". The use of the equation is illustrated in lecture 5 by the simple pull of a rod and bending of a beam, and (in the notes) by the flow and rotation of a fluid.

The sixth and subsequent lectures are concerned with more difficult problems. A consideration of creep leads to the linear superposition of the classical equations in a form which gives a material which is elastic over short time periods and in finite times flows like a liquid (Maxwell Liquid). Another linear superposition shows the property of elastic after effect (Kelvin solid). The general linear equation contains five material constants, but these have a definite meaning only when the rheological equation of state is given. Spring-cum-piston models of these materials are discussed in conjunction with a general account of structure models (lecture 7).

A further example of the general linear equation is given by the Saint-Venant body which is elastic up to a certain stress and then exhibits plastic flow. This problem is further treated by finding the work done from the stress and strain tensors, and deducing the Mises-Hencky flow condition. In the general case, there are kinetic, potential (i.e. elastic) and dissipated (thermal) energy and the relative preponderance of these three forms of energy expresses the rheological condition of a body. The flow condition shows that a Kelvin solid fails when the strain reaches a definite limit, and the stress at which the material fails increases with the velocity of strain. On the other hand a Maxwell liquid fails when the stress reaches a definite limit and the rate of strain at which failure occurs increases with the rate at which the stress is applied.

In the ninth lecture, the resolution of Tensors is discussed (and applied to the Saint-Venant principle for yielding) and illustrated by the Mohr circle. Dimensional analysis is illustrated by the Hagen-Poiseuille equation for flow in capillaries.

Still another special case of the general linear rheological equation gives the phenomenon of plastic viscosity above a yield point (the Bingham solid) characteristic of paints, clay suspensions and so on.

When the five constants in the general linear equation of state are functions of the state of stress and strain, still more complex behaviour may be derived, in particular that of the non-Newtonian liquid. The general linear equation shows that every material may be regarded as having a Kelvin and a Maxwell component with the St.-Venant yield stress dividing flow from deformation (lecture 10). Zero yield stress gives a liquid; breaking stress less than yield point a brittle solid; yielding before breaking a plastic solid. The terms "liquid" and "solid" are, however, relative (lecture 10).

The bibliography is restricted to references additional to

Bingham's rheological index. Except in the postscript no reference is made to dilatancy, thixotropy, tackiness, anomalies such as the sigma-phenomenon, slippage, cohesionless soils, and the psycho-physical aspects of measurement, or the theory of measuring instruments.

In connection with the classification of rheological properties, the author proposes a structural formula showing the components in terms of the "bodies" introduced in his book, and the rheological equation of state. The condition under which the coefficient of viscous traction is three times viscosity are discussed. R.L.B.

A Survey of General and Applied Rheology. G.W.Scott Blair. Pitman and Sons. 1944.

A valuable addition to the all too small library of British books dealing essentially with rheological matters. Although relatively small, this book is most comprehensive and is intended primarily for the practical rheologist and it does not attempt to be either a complete account of rheological investigations or a work for academic physicists.

After a preliminary introduction the author deals in some detail with rheological phenomena and their measurement, the latter aspect being dealt with in an extensive and practical manner. Part 2 of the book deals with rheological interpretations and the evidence of psycho-physical investigations. This final section is of particular interest as it is not widely realised how great a part the subjective testing of materials still plays in industry, and although the size of the volume precludes more extensive treatment, very adequate references are included which will enable the student to pursue any point of particular interest. D.C.B.

Institute of Petroleum Standard Methods. 1944.

The fifth edition of this authoritative book has just been published and there are several matters of rheological interest which should be noted. In particular there has been inserted a test (80/44 P) for the Breaking Point of Asphaltic Bitumens which is a modification of the Fraass method. There are modifications to the tests for Dropping Point of Greases and Bitumens (31/44); Penetration of Bituminous Materials (49/44); Viscosity by Redwood Apparatus (70/44); Viscosity (Kinematic) in Absolute Units (71/44 T), whilst certain other rheological tests remain unaltered, in particular the test for Liquid Asphaltic Bitumen (72/42) and Viscosity Index (73/42) D.C.B.

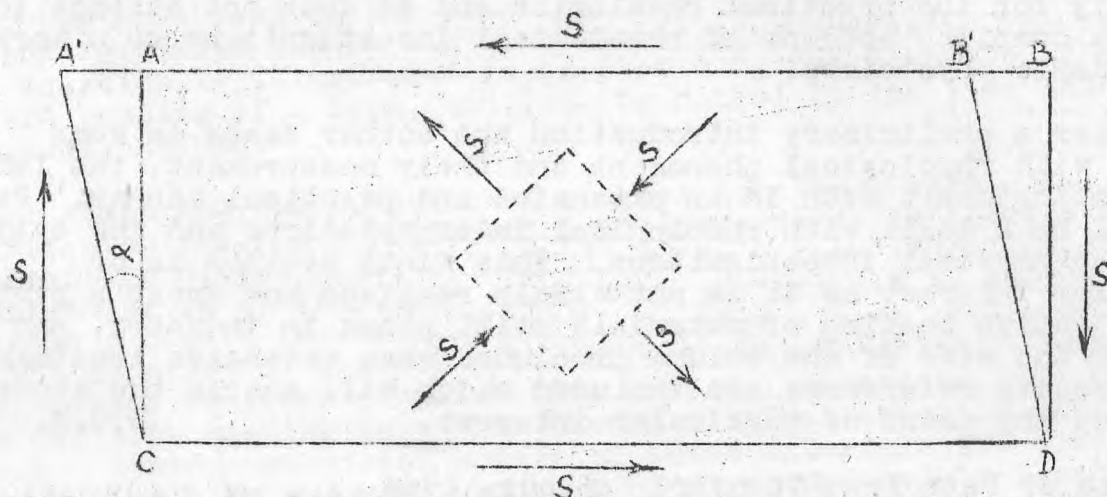
Prediction of the result of a shear test from the
result of a uniaxial tension or compression test

(The Hon.Secretary has received the following report from Dr. R.K. Schofield who was Chairman of the meetings described. It is intended for the use of members only and should not be referred to as a published paper or in a published work.)

Desiring guidance on this question, the Committee of the British Rheologists' Club sought the help of Prof.E.N. da C.Andrade, F.R.S., Mr.L.R.Brown, Dr.P.P.Ewald, Dr.H.Fröhlich, Mr.W.Lethersich, Dr.R.K. Schofield, Dr.G.W.Scott Blair, Prof.G.I.Taylor, F.R.S., Dr.L.R.G. Treloar and Dr.S.Whitehead. These, with the exception of Prof.Andrade and Prof.Taylor who were unable to be present, met at Brown's Hotel, Albemarle Street, W.1. on September 24th, 1943. Dr.Schofield took the chair and Dr. Scott Blair acted as Secretary. A memorandum prepared by Dr.Treloar and circulated before the meeting was considered. A letter criticising certain points in Dr. Treloar's presentation was

received from Prof. Taylor. At a second meeting, held on December 17th, 1943, Mr. Brown, Dr. Fröhlich, Mr. Lethersich, Dr. E. Orowan, Dr. Schofield, Dr. Scott Blair, Prof. Taylor, Dr. Treloar and Dr. Whitehead were present. A memorandum prepared by Dr. Orowan was approved. Dr. Schofield agreed, as chairman, to submit a brief report to the B.R.C. Committee in a form suitable for inclusion in the Club's Bulletin.

Shear Test.



The rectangle ABCD represents the cross-section of a rectangular block not under stress. In a shear test, shearing stresses are applied to the faces represented by AB and CD as indicated. If the shear is to be uniform throughout the whole block, shearing stresses of magnitude S must simultaneously be applied to the planes of the material that are perpendicular to AB and CD (different material planes come into this position as shearing proceeds). A discussion of the experimental arrangements by which these conditions of test are exactly or approximately fulfilled, falls outside the scope of this report.

I.. Perfectly Elastic Solid

(a) Small deformation of an isotropic elastic solid

If CD remains fixed and AB is displaced to A'B' by applying the shearing stresses, the resulting strain is expressed as AA'/AC or $\tan \alpha$. The modulus of rigidity, n , is given by

$$\tan \alpha = S/n$$

The state of stress may be considered to arise from a tensile and compressional stress each of magnitude S , mutually perpendicular and both at 45° to the shear planes (the planes represented by A'B' and CD). These are the principal stresses. It can be shown that the fractional elongation in the direction of the tensile stress and the fractional contraction in the direction of the compressional stress are both equal to $\frac{1}{2} \tan \alpha$ when α is small.

Again, because the deformation is small, the fractional elongation in the direction of the principal tensile stress may be considered to consist of S/E , due to the tensile stress, and $\sigma S/E$, due to the compressional stress acting at right angles to it: where E is Young's Modulus and σ is Poisson's ratio.

Hence:

$$\frac{1}{2} \tan \alpha = \frac{1}{2} S/n = S(1 + \nu)/E,$$

leading to the well known expression

$$n = E/2(1 + \nu)$$

Since E and ν can be found from uniaxial tension or compression tests, n is thereby determined.

(b) Large deformation of an isotropic elastic solid

We will suppose the shear test to be carried out in such a way that A'B' is at the same perpendicular distance from CD as AB, but $\tan \alpha$ is not small. In this case the stress acting on the shear planes may have a normal component N (considered positive if compressional) as well as the shearing component S . The principal tensile stresses, T , and the principal compressional stress, C , while still mutually perpendicular, are no longer at 45° to the shear planes, and are not necessarily of equal magnitude. The principal tensile stress must coincide with the direction of greatest elongation in the solid and the principal compressional stress to the direction of greatest contraction. If the greatest elongation is in the ratio r , the greatest contraction must be in the ratio $\frac{1}{r}$ (since there is no change in volume), and

$$\tan \alpha = r - \frac{1}{r}$$

The angles, θ and ϕ , made by the principal tensile and compressional stresses respectively with the shear planes are such that

$$\cot \theta = \tan \phi = r$$

and

$$N = Sr - T = C + S/r$$

No way is yet known, however, by which the principal stresses corresponding to a particular value of r can be computed from the results of uniaxial tension or compression tests. There is no reason to expect that, in general, the deformations which occur when the principal stresses act jointly can be expressed as the sums of the deformations occurring when equal uniaxial stresses act singly.

II. Inelastic Viscous and Plastic Solids

(a) Inelastic isotropic solid with constant viscosity

Such a material, in a shear test, gives the relationship

$$d \tan \alpha / dt = S/\eta$$

where η , the coefficient of viscosity is independent of S . The principal stresses are the same as in I(a). If two particles in the plane of the diagram are separated by distance ℓ , it can be shown that, when the line joining them coincides with the direction of the tensile stress,

$$\frac{1}{\ell} \cdot \frac{d\ell}{dt} = \frac{1}{2} d \tan \alpha / dt$$

and when it coincides with the direction of the compressional stress

$$\frac{1}{\ell} \cdot \frac{d\ell}{dt} = \frac{1}{2} d \tan \alpha / dt$$

Such a material acted on by a tensile stress S alone would suffer an

elongation rate S/T , where T is Trouton's coefficient of viscous traction. Since viscous flow entails no change in volume, the simultaneous rate of lateral contraction is $\frac{1}{2}S/T$. In the shear test we have a principal tensile stress, S , and a principal compressional stress, S , acting simultaneously at right angles to each other. Because T is independent of S and of the extent of the deformation, we can regard $\frac{1}{e} \frac{d\ell}{dt}$ in the direction of the principal tensile stress as made up of S/T , due to the tensile stress, and $\frac{1}{2}S/T$ due to the principal compressional stress acting at right angles to it.

Hence

$$\frac{1}{2} \frac{d \tan \alpha}{dt} = \frac{1}{2} S / \eta = \frac{3}{2} \frac{S}{T}$$

giving Trouton's relationship

$$\eta = \frac{1}{3} T$$

(b) Inelastic isotropic solid with viscosity varying with S

In this case T varies with S . Hence the rates of elongation and contraction in the directions of the principal stresses in the shear test are not the sums of the rates of elongation and contraction brought about by the tensile and compressional stress of magnitude S acting separately.

III. Visco-Elastic Solid

(a) Flow with constant viscosity combined with small elastic deformation in an isotropic solid.

The treatment in Ia and IIa may be combined. E and σ are found from the fractional changes in length and width on release of uniaxial stress, T , from rate of change of length while under constant uniaxial stress.

Conclusion

A rigorous deduction of the result of a shear test can be made from the result of a uniaxial tension or compression test on an isotropic solid only when there is either a small elastic deformation or viscous flow with constant viscosity, or a combination of the two.