

BRITISH RHEOLOGISTS' CLUB.



Address for Communications :
(till October 5th 1945)

c/o THE NATIONAL INSTITUTE FOR
RESEARCH IN DAIRYING,
SHINFIELD, READING.

Circular No. 9. August, 1945.

Issued for the information
of members of the Club only.

CLUB NOTES.

MEMBERSHIP. Membership continues to increase. On August 1st the Hon. Secretary had 300 names on his books.

FUTURE MEETINGS.

The Committee very much regrets that, owing to war-time conditions, it has not been possible to arrange a week-end conference during the summer of 1945. Plans for a conference in 1946 are now being considered.

The Annual General Meeting will be held in Manchester on the morning of Friday, October 5th. Nominations for Officers and Committee members for the ensuing year should be sent to the Hon. Secretary as soon as possible. In the afternoon of the same day, there will be a joint meeting of the Club and the Manchester Section of the Oil and Colour Chemists' Association. The subject for discussion will be "General Rheological Properties of Suspensions." The President of the Club hopes to be present.

Following the very successful meeting at Farnborough, it is hoped that a joint meeting with the Royal Aeronautical Society may be arranged during next winter.

Owing to a regrettable mistake, a few members may not have received notices of the Farnborough meeting (June 16th). If there are any such, the Hon. Secretary hopes that they will accept his profound apologies.

PUBLICATIONS.

The Committee has passed for Press a book written by its members which gives an account of the week-end Conference held in Oxford last year. This is being published by Sir Isaac Pitman & Sons and it is hoped that it will be available by the end of the year under the title "Essays in Rheology."

Additional copies of the Symposium on Tack reported in Paint Technology may be obtained from the Editor, 5, Grange Court, Pinner, Middx., price 2/-.

CO-OPERATION WITH RHEOLOGISTS IN ALLIED COUNTRIES.

While close co-operation is maintained with the (American) Society of Rheology, we are also glad to report new contacts with rheologists in the U.S.S.R. Through the courtesy of the U.S.S.R. Society for Cultural Relations with Foreign Countries, the Hon. Secretary and a number of other members have received copies of books and papers on rheology, including the proceedings of a Conference on Viscosity of Fluids and Colloidal Solutions held in Moscow in Spring, 1941. Very cordial letters have been exchanged between the President of the Club and Prof. M. P. Volarovich, the leading Soviet rheologist. Members will, of course, be already aware that Professor Andrade has recently visited the U.S.S.R.

It is hoped to establish contact with rheologists in other European countries as soon as possible.

A LETTER TO MEMBERS OF THE BRITISH RHEOLOGISTS' CLUB

From the Honorary Treasurer.

"INGLEMERE,"

DAGDEN ROAD, SHALFORD,
GUILDFORD, SURREY.

August 20, 1945.

DEAR FELLOW MEMBER,

At the next Annual General Meeting of this Club I shall have to ask for authority to increase your subscription from the present 5/- to £1-0-0. This is a step which your Committee much regrets, but I believe that when the circumstances are explained, you will see the reason for it.

When Dr. Scott Blair, Dr. Lang and I started this Club in October 1940, we thought we should probably have a membership of about 40; and we thought that a subscription of 5/- would cover the costs of postage and stationery and any other small expenses that might be involved. We never thought that the membership would swell to about 300—and it is still increasing. The size of our Club now makes it necessary that we should secure some part-time assistance for our Secretary.

During the past five years Dr. Scott Blair has carried out his duties as Hon. Secretary only with the help of Miss Milligan, who has done the work of duplicating and addressing envelopes; and I know that if the history of this Club ever comes to be written, it will record the heavy debt which the Club owes him. A new Hon. Secretary will be appointed at the Annual General Meeting, but your Committee has agreed that we cannot, as a Club, expect him to shoulder this quite heavy burden (which has to be done very largely in spare time) without remuneration or paid assistance.

Unfortunately, the mathematics of the position are very simple. We have no source of income apart from subscriptions. 30 subscriptions of 5/- give a total of £75, which is enough to cover present costs of postage and printing and incidental expenses—but that is all. To provide adequate paid secretarial assistance we shall have to raise about £150; and now that the war is over and we are intending to increase our activities, expenses are bound to increase as well. We are therefore aiming at an annual income of about £300.

This proposed increase in subscription will not take effect without the approval of the membership as expressed at the Annual General Meeting, and opportunity will be given for expression of views on the subject. The purpose of this letter is only to let you know beforehand what the position is. We regret that a higher rate of subscription has become necessary, but think that you will agree that it cannot well be avoided.

Yours truly,

V. G. W. HARRISON,
Hon. Treasurer.

RHEOLOGY ABSTRACTS.

Note.—The Club assumes no responsibility for the opinions expressed by abstractors. These are given in square brackets.

254. Flow Properties of Coating Clays at high rates of Shear.

K. A. ARNOLD. *Paper Trade J.*, 117, No. 9, 28, 1943.

A procedure 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 measure-

ment, the slip is also subjected to pressures comparable 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 dilatance 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. A technique has been developed to ensure reproducibility of the measurement of flow properties. The variables involved have also been investigated. At high rates of shear, the "nip" viscosities of clay slips were found to be critically dependent upon 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. It was possible to prepare a fluid slip with a high concentration of the clay possessing the smallest particle size and least hydration capacity. A much lower concentration was attainable with the clay of the highest particle size and highest hydration capacity. The third clay, which showed the largest particle size but the lowest degree of hydration, was found to be intermediate as to maximum possible concentration in a fluid slip. 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. This was true with either dispersing agent— $\text{Na}_4\text{P}_2\text{O}_7$ or Na silicate. However, the amount of Na silicate used as the dispersing agent is much more critical than that of $\text{Na}_4\text{P}_2\text{O}_7$. In general, the flow properties of clay slips were found to change considerably with the amount of mechanical work to which they were subjected. On ball milling, the slips showed an initial decrease in viscosity over several hours of milling. The test for hydration of the clay particles indicated a gradual increase in this property during milling. Greater changes took place during milling in slips containing comparatively low percentages of the dispersing agent. In the preparation and application of coating clay colours, the mechanical work applied to the colour should be carefully controlled in order to produce uniform coating. 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 were actually thixotropic under high shear. Thus, it follows that viscosity measurements made at one rate of shear, or at relatively low rates of shear, have little significance as an index of the flow behaviour at high rates of shear. By a careful selection of the amount of work applied, the amount of dispersing agent used, and the concentration of clay, it was possible to prepare slips from different clays which showed very similar flow properties. B.R.R.A.

255. Some Rheological Properties of Polyvinyl Chlorides.

L. BILMES. *J. Soc. Chem. Ind.*, **63**, 182, 1944.

The rheological properties of plasticised polyvinyl chloride have been studied in a specially constructed torsion apparatus over the temperature range— 70° to 100° C. The results obtained have been analysed and their significance is related to considerations of molecular structure. On raising the temperature the material passes through four states—the glassy, leathery, rubbery, and plastic states, and it has been found possible to characterise these states by values of the constants of the Nutting equation. The apparatus used in the experimental work was as follows:—The base of a cylindrical sample of the material under test was attached to a fixed brass plate, while the top of the sample was attached to a circular brass plate on a spindle. The method of attachment consisted of moulding the ends of the sample into the interstices of heated copper gauze and clamping the gauzes to the plates. The spindle could be

rotated so as to twist the top of the sample relative to its base. A fine cord passed around a drum, attached to and concentric with the spindle, and over a pulley wheel to a scale pan in which weights could be placed. The upper end of the spindle carried a pointer so that the torsion of the cylinder could be read off on a scale attached to the frame-work of the apparatus. A small mirror was also attached to the top of the spindle so that very small angles of twist could be read by the movement of a spot of light on a scale. The apparatus could be fixed rigidly into a thermostat. The bearings for the spindle and the pulley were provided by bicycle-wheel hubs and suitable precautions were taken to ensure the absence of frictional effects.

B.R.R.A.

256. **A Theory of Calendar Effect in Rubber-like Materials.**

L. BILMES. *Trans. Faraday Soc.*, **41**, 81, 1945.

Experiments on the retraction of calendered polyvinyl chloride sheet, with rising temperature, and on the stress developed when the retraction is prevented, are presented. The results may be interpreted on the basis of a model containing springs and dashpots having temperature-dependent yield values.

L.R.G.T.

257. **A Note on the Representation by Model Systems of the Behaviour under Stress of Rubber-like Materials.**

L. BILMES. *Journal Scientific Instr.*, **22**, 16, 1945.

The "spring-dash pot" model systems are applied to the study of deformation under constant stress (Alexandrov and Lazurkin) and that of relaxation under constant deformation (Kuhn etc.) of rubber-like materials and the model systems are shown to be mathematically identical.

H.C.T.

258. **The Theory of Indentation and Hardness Tests.**

R. F. BISHOP, R. HILL and N. F. MOTT. *Proc. Phys. Soc.*, **57**, 147, 1945.

A discussion is given of the indentation of ductile materials by cylindrical punches with conical heads. On the experimental side, experiments have been made with work-hardened and with annealed copper, with penetrations up to nine times the diameter of the punch. It is found that the load rises towards a maximum value which is not approached until the base of the cone has travelled four to five diameters into the copper block. Denoting the maximum load by $p_0 A$, where A is the area of the cross-section of the punch, it is found that p_0 for a lubricated punch is about twice the hardness, or five times the yield stress of the work-hardened material. A theoretical method is given for calculating p_0 , as follows: the pressures p_c and p_s required to enlarge a cylindrical and a spherical hole in a material showing any kind of strain hardening can be calculated. It is plausible to assume that p_0 should be between p_c and p_s , and since p_s is only slightly greater than p_c , an approximate theoretical estimate of p_0 is obtained. This is in good agreement with experiment. In the light of these results a qualitative discussion is given of hardness testing, and it is shown both on experimental and on theoretical grounds that with lubricated cones and work-hardened materials, the hardness, i.e. load-indentation area, will not depend much on the angle of the cone unless this is less than 10° .

[AUTHORS].

259. **The Fluidity of Nylon Solutions in m Cresol.**

J. BOULTON and D. L. C. JACKSON. *J. Soc. Dyers and Colourists*, **61**, 40, 1945.

m cresol is the most suitable solvent for routine viscometry work on nylon yarn from the point of view of evaluating textile damage and is preferred to formic acid. Approximately linear relationships exist between fluidity and loss in strength for chemical damage by sulphuric acid or photochemical activity.

E.W.J.M.

260. **The Viscosity of Dilute Solutions of Nitrocelluloses derived from chemically modified Cotton Cellulose of various types.**

T. BROWNETT and C. F. DAVIDSON. *J. Textile Inst.*, **36**, T.1, 1945.

The relations between viscosity and concentration of acetone solutions of nitro-celluloses derived from hydrocellulose and dichromate oxycelluloses and periodic acid oxycelluloses were investigated over the range of concentration 0 to 0.25 per cent. The relation between viscosity and concentration for all three types of nitro cellulose is satisfactorily expressed by the equation $\log \eta_{sp}/c = \log [\eta] + mc$ where m is a constant. The qualitative behaviour recorded above is expressed formally by the fact that within a series of nitro celluloses derived from a given type of modified cellulose, m increases with $[\eta]$ but the relation between m and $[\eta]$ varies from one type of modified cellulose to another. E.W.J.M.

261. A study of Constant-stress Rheometers.

J. E. CAFFYN. *J. Sci. Instr.*, **21**, 213, 1945.

It has been shown that constant-stress rheometers, i.e. rheometers in which the tensile or compressive force changes as the cross-sectional area of the sample changes, can be made utilising a bent lever for the application of the tensile or compressive force. The equations governing the operation of the instruments are deduced for deformations at constant volume, from which the amount of deformation, the initial and final height or length of sample, and the working range of the instrument can be obtained. In addition the bent lever serves as a basis for the classification of such constant-stress rheometers. B.R.R.A.

262. The Measurement of some Physical Properties of Curd and Cheese during manufacture of cheese.

J. E. CAFFYN. *Dairy Ind.*, **10**, 257, 1945.

This paper describes the continuation of work already published by Coppen [*Dairy Industries*, **8**, 488 (1943).] on the use of certain simple machines for measuring the mechanical properties of cheese and cheese-curd in the factory. The present paper is concerned with war-time Cheshire: Coppen worked mainly on Cheddar.

The consistency of curd at pitching was measured by the Scott Blair-Coppen method and the sectility during "cheddaring" by means of an improved sectilometer. Other rheological properties were also measured before milling by means of a constant stress rheometer. The consistency of the finished cheese was measured by means of an improved model of the ball-compressor (Brinell principle). Permission was obtained to cut samples from a small number of cheese and these were also tested with the rheometer.

Correlations were worked out to establish, for example, the quantitative effects of known variations of consistency at pitching or sectility at milling on the firmness of cheese during the process of ripening.

Excellent correlations were found between measurements of consistency during manufacture and the condition of the green cheese; but as ripening proceeded, the correlations tended to become less clear. This emphasises the very great importance of ripening conditions in controlling final quality.

The two most important factors which can now be measured with accuracy during manufacture would seem to be the consistency at pitching and the sectility at milling. The former was found to be correlated with the solids-not-fat of the milk but it should be pointed out that in the factory when the tests were made, pitching was "by the clock."

A constant stress rheometer really suited to the testing of curd before milling has not yet been built but even the admittedly unsatisfactory instrument available gave interesting results.

The importance of uneven distribution of moisture in cheese both to quality and in relation to sampling difficulties, is stressed. G.W.S.B.

263. Viscosity Measurement.

M. R. CANNON. *Ind. Eng. Chem., Anal. Ed.*, **16**, 708, 1944.

This paper describes the construction and operation of two types of master

viscometers designed for accurately calibrating the various types of routine viscometers now in extensive use. The first instrument is calibrated directly with water at 20°C. The remaining instruments of larger bore are then calibrated against the first by means of hydrocarbons of suitable viscosity. These calibrated master viscometers are used to establish accurately the viscosity of a whole series of calibrating fluids to be used in calibrating routine viscometers. Since some fluids change in viscosity with age, the master instruments are employed to check the standard fluids two or three times per year. The opaque-type master is useful in handling very dark or opaque liquids and in studying the drainage effect in viscosity measurements.

B.R.R.A.

264. **Properties of Alginate Rayons.**

N. H. CHAMBERLAIN, A. JOHNSON and J. B. SPEAKMAN. *J. Society of Dyers and Colorists*, **61**, 13, 1945.

The elastic properties of alginate rayons are described (a) as a function of metal content and (b) as a function of the relative humidity of the atmosphere. The extensibility of chromium and beryllium alginates is much too low to permit their successful use in weaving and knitting. Calcium alginate rayon possesses satisfactory elastic properties for these purposes.

E.W.J.M.

265. **Measurement of the Viscosity of Wall-Adjacent Boundary Layers of Liquids by the Blow-off Method.**

B. DERJAGUIN, G. STRAKHOVSKY and D. MALYSHEVA. *Acta Physicochimica U.S.S.R.*, **19**, 541-552, 1944.

The behaviour of a thin film of oil was investigated by the measurement of the profile of the liquid remaining on a surface if exposed to a stream of air passing above it. For normal liquids the viscosity in the very thin films was found to be the same as in bulk; addition of a small amount of aluminium naphthenate to straight mineral oil increases the measured viscosity by tenfold in the nearest proximity of the walls, without increasing materially the viscosity in bulk. This increase is assumed to be due to an interaction between wall and liquid.

L.A.S.

266. **Theory of Filler Reinforcement.**

JANE M. DEWEY. *J. Appl. Phys.*, **16**, 55, 1945.

Criticises the paper by J. Rehner, Jr. (*J. Appl. Phys.*, **14**, 638, 1944) in which the stresses in the neighbourhood of a spherical filler particle in rubber are discussed. Using Goodier's analysis of such a system it is indicated how the elastic properties of filled rubber can be calculated.

R.S.R.

267. **Place-exchange Theory of Plastic Flow as applied to Polymers.**

D. D. ELEY and D. C. PEPPER. *Nature*, **154**, 52, 1944.

In a theory advanced by Eyring the flow process is regarded as the movement of a molecule, or segment of a molecule, from one position in the plastic to a neighbouring one, under the influence of thermal energy. If E be the potential barrier separating two positions, and f the stress, then the activation energy for the process is written as $E - bf$, where b is a constant involving the dimensions of the "unit of flow." The rate of flow, θ , may then be written: $\theta = \text{const.} \cdot e^{-(E-bf)/RT}$ from which it can be shown that for very low stresses the system will show Newtonian behaviour. Eyring has treated simple liquids along these lines. For $bf > RT$ the following behaviour is predicted: $\log \theta = a + b'f$. The authors have recently completed an extensive series of measurements on a plasticised cellulose derivative over a stress range 2-160 kgm./cm.² and temperature range 16-100°C. The methods used were compression of cylinders and extension of rods, care being taken to analyse the total strain into its plastic (non-recoverable) and elastic components. The important result of the work is that $\log \theta = a + b'f$ is followed only at the lower stresses, that is, up to a certain stress value f_0 which is itself a function of temp. It has been

found that the "activation energy" for flow falls from about 30 kcal at 4.6 kgm./cm.² to about 11 kcal at $f > f_0$. The flow may be described by the equation originally used by Bingham to describe the flow of solid-liquid dispersions through capillary tubes. No indication was found of a true yield-value. At very low stresses, in extension, the material shows strain-hardening, θ falling 20-30 fold over the initial 3 to 4 per cent. extension, reaching an apparently steady value. At the high stresses used in compression no such behaviour could be detected. It appears that any strain-hardened structure which may be formed initially cannot withstand the large shearing forces produced by the high stresses operative in the compression measurements.

B.R.R.A.

268. The Thermodynamics of Rubber at Small Extensions.

D. R. ELLIOTT and S. A. LIPPMANN. *J. Appl. Phys.*, **16**, 50, 1945.

On analysing their own data, Meyer and Ferri have concluded that at small extensions, rubber is an ideal elastomer according to the definition that $(\delta E/\delta L)_{P,T} = 0$. (E = internal energy, L = length). Further, analysis of Meyer and Ferri's data does not sustain their conclusion. If, however, $(\delta E/\delta L)_{V,T} = 0$ is taken as a new criterion for an ideal elastomer, Meyer and Ferri's data do indicate that rubber is ideal, at least for extensions up to 166 per cent. The new criterion implies that the valence angles do not store an appreciable amount of energy when the rubber is stretched. However, both the molecular orientation and the inter-atomic displacements do influence the energy required for extension.

AUTHOR'S ABSTRACT.

269. The Variation with Temperature of the Dynamic Properties of Rubber and Synthetic Rubber-like Materials.

W. P. FLETCHER and J. R. SCHOFIELD. *Journal Scientific Insts.*, **21**, 193, 1944.

The dynamic elastic compression modulus and the resilience of several types of Neoprene, Perbunan, Buna N, Hycar, Buna S, Thiokol RD and of natural rubber were measured in the temperature range of 0-40°C. Bonded blocks of each supported a vibrator of the rotating off-balance type and it was found that the natural rubber was the least temperature sensitive in respect of the above properties.

H.C.T.

270. Stress-strain Curves of Paper.

E. R. GIBBON. *Paper Maker*, **108**, TS53, 1944.

A study is made of the stretching properties of paper under tension and its recovery on removal of stress. All tests were carried out on crease-free strips, 108 in. long by 1 in. wide. Tension was applied by charging kilo and $\frac{1}{2}$ kilo weights into a pan suspended by the test strip, and the alterations in length were measured in 1/64 in. over a measured 100 in. Unless otherwise stated, all tests were conducted

(1) at 70°F. $\pm .5^\circ$ and 65% Rel. Humid. $\pm 1\%$.

(2) with strips cut in the machine direction

(3) with load changes approximately at 20 sec. intervals.

Recoveries from the different peak loads were for separate strips of the same paper.

A number of graphs are drawn from the averages of multiple tests. The ascending tracks show percentage stretch against load up to breaking point, and the descending tracks show recovery on successive removals of load back to zero from various peak loads. Two graphs are given showing the effect of Rel. Humid. and temp. of stressing. The differences between machine and cross directions are also illustrated. Curves for different papers are very similar in general shape. An empirical relation

$$S = F(L^2 + 5L) \quad (S = \text{stretch}, L = \text{load}, F = \text{const.})$$

has been found to fit the data for a number of graphs with a moderate degree of accuracy, but no explanation for this result is offered. It is found that successive loadings and unloadings applied to the same strip of paper give similar loops and there is only a small increase in permanent set.

[The work is interesting as far as it goes and the curves are of the form one would

expect. Too little attention, however, has been given to the time variable. The increase in "permanent set" with number of loadings does not appear from the data given to be at all "negligible" and seems to point quite clearly to slow viscous flow in addition to the initial elastic extension and non-recoverable stretch. This is a case, too, where it might be advantageous to take strain as an independent variable and to measure the stresses developed when the paper is strained at various and definite rates. It is not surprising that the empirical relations which the author has tried are not very satisfactory, since they ignore the time factor entirely.]

V.G.W.H.

271. Solutions of some problems in Viscous Flow.

G. GREEN. *Phil. Mag.*, **35**, 250, 1944.

Solutions are given for viscous flow within certain specified boundaries, using a method involving the application of conjugate functions. After a general examination of the problem, the special cases of flow between converging plane walls and flow into a parallel channel are considered.

B.R.R.A.

272. Some Physical Properties of Elastomers at Low Temperature.

H. E. GREENE and D. L. LOUGHBOROUGH. *J. Appl. Phys.*, **16**, 3, 1945.

The effect of testing time on log (elastic modulus) vs. temperature curve is investigated for various rubbers. It is found that the sharpness of the transition between the elastic and glassy states becomes more and more pronounced as the testing time is decreased, and the temperature at which the transition begins to take place is increased. The effect of addition of plasticisers is generally the same as that of increase of temperature. Also, addition of reinforcing materials decreases the sharpness of the transition without changing the position of the curve. The effect of the amount of styrene in a butadiene-styrene copolymer is investigated.

R.S.R.

273. The Significance of pH in the control of the properties of clay.

R. E. GRIM. *Illinois Geol. Surv. Bull.*, No. 68, 268, 1944.

The complex nature of clay is indicated and the possibility and significance of base exchange reactions are pointed out. Discussing the effect of the base present in a clay on its workability, it is stated that the order of increasing yield point with a given water content is approximately Li, Na, Ca, Ba, Mg, Al, K, NH_4 , H. The order of increasing stiffness with a given water content is about the same. Available data suggest that Na clays have high, Ca clays intermediate, and H clays low, dry strength; Na clays have high fired strength. Clays saturated with H dry the most rapidly, while Na clays dry the slowest; the effect of base exchange on the shrinkage is not clear. The effect of exchangeable bases on the texture of a clay is also discussed. The significance of these observations is considered.

B.R.R.A.

274. Theory of Filler Reinforcement.

EUGENE GUTH. *J. Appl. Phys.*, **16**, 20, 1945.

For small loadings (up to about 10 per cent. volume parts) the colloidal carbon black spheres may be considered as suspended in a continuous rubber matrix. In the present paper this model is generalized for ellipsoidal (including plate- and rod-like) filler particles and it is extended to the computation of various properties of the suspension in terms of the properties of the matrix and of the fillers. Viscosity, Young's modulus, stress-strain curve below crystallization, and dielectric constant of the suspension are derived as linear functions of the volume concentration for small, and as quadratic functions for higher loadings. The stress-strain curves for varying amounts of fillers are similar. For small loadings the tensile strength first decreases because of the stress concentration occurring around the carbon black spheres when the samples are stretched. The increase of the tensile strength observed for greater loadings is caused by the tendency to form chains and finally, a

type of network. The stiffness increases with loading, up to the point where the suspension becomes a dilution of carbon black by rubber. There the tensile strength decreases too. Binding of rubber by carbon black is similar to solvation. The theoretical conclusions were checked experimentally, in particular, the dependence of Young's modulus on concentration, the similarity of stress-strain curves, and the decrease of the tensile strength for small loadings. The theory of the elastic properties is very similar to the theory of Einstein on the viscosity of colloidal solutions and to Maxwell's and Rayleigh's theory of dielectric properties.

AUTHOR'S ABSTRACT.

275. Survey of the Literature on Plasticity, Viscosity and Allied Properties.

P. G. HEROLD and W. J. SMOTHERS. *Bull. Amer. Ceram. Soc.*, **23**, 184, 1944.

A search of the literature and a grouping of the methods used in various industries for measuring plasticity, consistency, and viscosity show that most of the industries have standardised on the measurement of viscosity. Industries such as the ceramic, paint, rubber, and cellulose industries are still attacking the problem of plasticity. Characteristic apparatus used in each industry for measuring rheological properties is described.

B.R.R.A.

276. The structure of Cellulosic Rayons—the Viscosity of solutions of Cellulose Acetate.

F. HOWLETT, E. MINSHALL and A. R. URQUHART. *J. Textile Inst.*, **35**, No. 12, 1944.

An enquiry into some of the factors influencing the viscosity of solutions of cellulose acetate. The chief object was to find the best method of using viscosity data to obtain a measure of the mean chain length of the acetate molecules in solution.

The intrinsic viscosity $[\eta]$ was determined by two methods (a) making use of Baker's formula relating the viscosity of the sol with concentration, $\eta = (1 + pc)^n$ in the form $\eta^{\frac{1}{n}} = 1 + pc$, where p is a constant, and (b) the linear relationship between $\log \eta_{sp}/c$ and c (where c is concentration). The intrinsic viscosity of various cellulose acetates in acetone varied from 0.151 to 0.178 indicating chain lengths of from 351 to 415 according to the kind of cellulose acetate.

E.W.J.M.

277. The Basic Principles of Soil Compaction and their Application.

A. H. D. MARKWICK. *Inst. Civil Engrs.*, Preprint, Nov, 1944.

The bulk density of the solid particles in the soil (commonly known as the "dry density") is a measure of the closeness of packing of the soil particles and hence of the state of compaction of the soil. Compaction increases the closeness of packing and hence the dry density of the soil, but in general only air is expelled from the voids to make up for the increased proportion of solids. With soil of given moisture-content, density increases with the amount of compaction at a decreasing rate until a limit is reached when only about 3 per cent. or less of air is left in the soil. With soils of varying moisture-content to which equal amounts of compaction are applied, a moisture-content exists at which a maximum dry density is obtained. The moisture-content at which this occurs is termed the "optimum moisture-content." Both the maximum density and the optimum moisture-content vary with the type of soil and the amount of compaction applied.

B.R.R.A.

278. Observations indicating absence of Plastic Flow in Glass Coating on Steel.

W. G. MARTIN and F. W. LAUCK. *J. Amer. Ceram. Soc.*, **27**, 352, 1944.

Steel rings were glass coated, and some were split at one point immediately and others one or two years later. Identical movement of the rings caused by compressive forces in the glass indicated that no plastic flow takes place in the glass. The compressive forces were calculated and found to be of the general order of 10,000 lb./sq. in. The method of calculation is described.

B.R.R.A.

279. **Mechanics of the Metal Cutting Process. I. Orthogonal Cutting and a type 2 Chip.**

M. E. MERCHANT. *J. Appl. Phys.*, **16**, 267, 1945.

An analysis of the chip geometry and the force system found in the case of orthogonal cutting accompanied by a type 2 chip has yielded a collection of useful equations which make possible the study of actual machining operations in terms of basic mechanical quantities. The shearing strain undergone by the metal during chip formation, and the velocities of shear and of chip flow are among the geometrical quantities which can be quantitatively determined. The force relationships permit calculation of such quantities as the various significant force components, stresses, the coefficient of friction between chip and cutting tool, and the work done in shearing the metal and in overcoming friction on the tool face. The experimental methods by which such analyses can be readily made are described. Observed and calculated values from typical tests are presented.

AUTHOR'S ABSTRACT.

280. **Retraction and Stress Propagation in Natural and Synthetic Gum and Tread Stocks.**

B. A. MROWCA, S. L. DART and EUGENE GUTH. *J. Appl. Phys.*, **16**, 8, 1945.

The extension *vs.* time curves of freely retracting rubber bars are obtained by attaching a stylus to the end of the bar and allowing it to trace out a path on a rotating smoked drum, for various initial elongations. Hevea, G-I-S and GR-I gum and tread stocks were investigated. For the Hevea gum it was found that the speed of retraction of the end increases fairly rapidly at first and then remains constant. Attaching additional styluses at the middle and quarter way positions of the bar, it was found that the end retracts for a considerable time before the other two styluses move appreciably. Some of the other stocks investigated show variations from this behaviour. Results of the investigation of retracting rubber by instantaneous photography using stroboscopic illumination and by Edgerton high-speed photography are described. The results of the experiments are interpreted in terms of the theory of James and Guth.

R.S.R.

281. **Differentiation of Hydrogen Clays and Identification of their mineral constituents by Electrochemical and Viscous Methods.**

J. N. MUKHERJEE and R. P. MITRA. *Nature*, **154**, 824, 1944.

An electrochemical method for differentiating hydrogen clays and identifying clay minerals contained in them has been developed; it is based on a comparison of their electrochemical properties with those of hydrogen colloids, isolated from natural deposits of the clay minerals. A method is also described for differentiating kaolinitic clays from those containing montmorillonitic minerals, based on the effect of the addition of caustic soda on the viscosity of aqueous suspensions of the hydrogen clays.

282. **Wave Equation for Finite Elastic Strains.**

A. NÁDAI. *J. Appl. Phys.*, **16**, 313, 1945.

Criticises the paper by Mrowca, Dart and Guth (*J. Appl. Phys.*, **16**, 8, 1945) on Retraction and Stress Propagation in Natural and Synthetic Gum and Tread Stock" on the grounds that in their mathematical analysis they use the classical equation for the longitudinal oscillation of an elastic bar which is valid only for small strains. The correct equation is derived on the basis of a linear stress *vs.* natural strain relationship.

R.S.R.

283. **Fundamental Study of Clay: V. Nature of Water Film in Plastic Clay.**

F. H. NORTON and A. L. JOHNSON. *J. Amer. Ceram. Soc.*, **27**, 77, 1944.

Using a monodisperse system of kaolinite particles of known diameter and

thickness, it has been possible to calculate with a fair degree of precision the thickness of the water film separating the particles and the variation in thickness of this film for different pressures. It has also been possible to calculate with considerable certainty the force acting between two clay particles. This clean, mono-disperse, fraction of kaolinite has the following characteristics: (1) The particles average 0.32 micron in diameter and 0.04 micron in thickness. (2) The water-film thickness in the plastic condition averages 0.005 micron, or about 60 molecular layers. (3) Under conditions of permeable pressing, the thickness of the film varies inversely with the pressure up to 600 lb./sq. in., above which distortion of the particles occurs. (4) The actual force acting between two particles varies between 0.13 and 0.0006 dyne. B.R.R.A.

284. Fundamental Study of Clay : VI. Flow Properties of Kaolinite Water Suspensions.

F. H. NORTON, A. L. JOHNSON and W. G. LAWRENCE. *J. Amer. Ceram. Soc.*, **27**, 149, 1944.

The flow properties of six monodisperse kaolinite fractions were studied over a large range of concentration. From these results, it has been possible to set up an equation relating viscosity to concentration which holds over a very wide area. Equations relating concentration to thixotropy and to the yield point which have general application could also be established. The viscosity of a suspension is obtained from the sum of three quantities, those contributed by the liquid, the individual particle, and the collisions of the particles. Thixotropy is found to be due to the sum of two quantities, the contribution of the individual particle and the interference of the particles. The yield point in these fractions was found to be proportional to the cube of the concentration. With these relations, it is possible to calculate the viscosity of a casting slip for any change in sp. gr. B.R.R.A.

285. The Fatigue of Glass under Stress.

E. OROWAN. *Nature*, **154**, 341, 1944.

The author shows that the decrease of the breaking stress with increasing duration of loading can be explained on the basis of the Griffith theory, and that in this way the ratio of the breaking stresses for very short and very long duration of loading can be calculated. B.R.R.A.

286. A Falling Co-axial Cylinder Viscometer for the rapid measurement of High Viscosities.

H. L. D. PUGH. *J. Sci. Instr.*, **21**, 177, 1944.

A falling co-axial cylinder viscometer has been developed for the rapid measurement of absolute viscosities over the range 5×10^4 to 10^{10} poises under known constant shearing stresses. The apparatus consists essentially of an inner hollow brass composite cylinder encircled by a brass cylindrical ring with a space between to contain the test material. Details in design that facilitate measurement and manipulation include devices for centring the inner cylinder during filling and during test; direct application of load to a lower extension from the inner cylinder, which provides stability to the falling system by ensuring that it remains vertical; and ability of the inner cylinder to travel an equal distance on either side of the mean position. Other advantages of this instrument are pointed out. Although the instrument is satisfactory for purely viscous materials it is not suitable for measuring the viscosities of materials having pronounced plastic (non-Newtonian) or elastic properties. B.R.R.A.

287. Viscosity and Rigidity of Structural Suspensions.

P. S. ROLLER and C. K. STODDARD. *J. Phys. Chem.*, **48**, 410, 1944.

The relation between viscosity and rigidity of structural suspensions is analysed,

employing in part original data for bentonite suspensions, and a basic interpretation is offered.

The occurrence of structural suspensions is wide, and rigidity may be present in suspensions containing less than 0.1 per cent. solids. During structural viscous flow the structure is broken and the suspension consists of a concentrically disposed composite of liquid suspension and undecomposed residue. The transition of a structural suspension from its rigid state during rest to its broken state during flow is analysed. It is indicated that equilibrium values for the structural viscosity may be closely realised.

At a sufficiently high mean rate of shear the structure is completely destroyed, and the condition of a suspension of discrete particles is attained, to which the Einstein equation may be applied.

The Ostwald-de Waele power equation, with exponent < 1 , describes the viscosity at zero rate of shear. The relation of this to a finite breaking strength or yield value is discussed.

[This paper deserves careful study, even though the conclusions seem to conflict with certain generally accepted ideas.] L.R.G.T.

288. High Tension Viscose Rayons.

L. ROSE. *J. Society of Dyers and Colorists*, **61**, 113, 1945.

The two fibres "Tenasco" and "Durafil" are described and stress-strain diagrams for fibres under different conditions are given. The work of rupture of the fibre (given by the area under the stress-strain curve) was found to be as follows:—

Ordinary viscose rayon	16.8 g. cm. per m. per denier
Tyre "Tenasco"	24.2 " "
"Durafil"	14.3 " "

Under ballistic loading conditions the figures are somewhat higher but still in the same relative order. E.W.J.M.

289. Casting Characteristics of Clays : I. Improved methods for Determination.

E. RUSSEL and W. C. MOHR. *J. Amer. Ceram. Soc.*, **27**, 97, 1944.

Methods are given for the determination of casting rate, permeability, water retention, thixotropy, fluidity, organic content, shrinkage, and dry strength. By determining the effect of varying increments of electrolyte on the foregoing properties, it is possible to select clays, which have desirable casting characteristics for commercial use. Samples of fast and slow casting china clays and ball clays were used to indicate the utility of the methods employed; results are also given for two composite bodies. In developing the test procedure using the Buchner funnel (vacuum), the effect of the following factors was determined: mixing procedure, ratio of clay to flint, felspar vs. flint as the nonplastic, electrolyte content, quantity of slip used, sp. gr. of slip, slip temperature, aging and vacuum pressure; the optimum procedure for testing clays was then evolved. B.R.R.A.

290. The Principle of Maximum Plastic Resistance.

M. A. SADOWSKY. *Trans. Amer. Soc. Mech. Eng.*, **65**, A-65, 1943.

A complete determination of stresses in a plastic body has hitherto been dependent upon a successful analysis of deformation in plastic flow, the method of computation being essentially based on Nádai's stress-strain relations. The principle of maximum plastic resistance, as introduced in this paper, establishes a new method of computation of stresses only, without any explicit reference to deformation. Formally, the principle is progressive, since it supplies equations sufficient for solution; intrinsically and physically, the principle treats the plastic body as a reacting medium

automatically producing maximum values of resultant reaction. Combined plastic tension, torsion, and inner pressure (e.g. in a boiler) are chosen as cases in which to apply the principle. The results are condensed in a diagram.

B.R.R.A.

291. **Extension of Viscose Syrup.**

P. C. SCHERER. *Rayon Textile Monthly*, **26**, Nos. 2 and 3, 1945.

When viscose syrup is allowed to drop freely from a rod, a characteristic phenomenon is the "stretching out" of the falling drop into a long filament which persists until complete separation of the drop occurs. The distance stretched before breaking was named Extension and this was found to be closely parallel with the viscosity of the syrup and independent of the surface tension.

E.W.J.M.

292. **A study of the firmness of Soft Materials based on Nutting's equation.**

G. W. SCOTT BLAIR. *J. Sci. Instr.*, **21**, 149, 1944.

The Nutting power-law relating shear stress, strain, and time has been applied to data derived from the compression and extension of cylinders and strips of soft materials each at a series of constant stresses, due compensation being made for changes in the cross-section of the test-pieces. The majority of curves so obtained are linear, plotting log strain against log time, comparatively few materials giving curves showing marked deviations from linearity. A comparison of the three constants (two "quality" exponents and one "intensity" factor) is made for a variety of materials, including clay. In spite of the dimensional difficulties inherent in the equation, the treatment appears to have considerable advantages over the more usual practice of calculating viscosities and shear moduli by dividing the strains into recoverable and non-recoverable components.

B.R.R.A.

293. **Notes on the Compressibility of Clays.**

A. W. SKEMPTON. *J. Geol. Soc.*, **100**, 119, 1944.

From laboratory tests and from data on sedimentation compression curves the following conclusions can be drawn. Both laboratory and sedimentation compression curves depend to an important extent on the type of clay, as revealed by its liquid limit or mechanical analysis. The more colloidal clays are more compressible and possess higher void-ratios under a given pressure than do the sandy clays and silts. In a very general way, the laboratory compression curve for a certain type of clay is similar to the sedimentation compression curve for that clay; but it falls below the sedimentation curve, and this discrepancy is particularly marked in the range of soft clays. It seems possible that under high pressures, resulting in stiff clays, the two curves approximate more closely. Data for comparison are lacking in the range of shales. Laboratory curves for undisturbed samples lie closer to the sedimentation curves than do those for slurries.

B.R.R.A.

294. **Viscosity Temperature Curves.**

L. A. STEINER. *Chemical Age*, **52**, 361, 1945.

Viscosity-temperature curves of liquids are divided into 3 groups: (1) reversible, (2) irreversible, (3) conditionally reversible.

The application of viscometric methods is discussed. Examples using Steiner viscometers are quoted for the reversible and conditionally reversible type of curve.

AUTHOR'S ABSTRACT.

295. **Undisturbed Clay Samples and Undisturbed Clays.**

K. TERZAGHI. *J. Boston Soc. Civil Engrs.*, **28**, 211, 1941.

If the state of stress in a clay changes extremely slowly, the effective pressure on the clay is transmitted from grain to grain exclusively by a bond between the solid part of the adsorbed films which surround the clay particles. So long as this solid bond is intact, the clay is in a solid state; it has the physical characteristics of a porous cemented material, the modulus of elasticity is high and its compressibility is smaller

than that of dense sand. When clay is stressed beyond a certain limit, the rigid bond between the clay particles breaks, and the particles become temporarily separated by water films. The clay is now in the "lubricated" state and is highly compressible; the clay particles can slide over one another until the water film has been removed and the particles are again in solid contact. When the consolidation of a clay is practically complete, all the stresses in the clay are effective stresses, but these stresses are partly carried by the highly viscous films of adsorbed water, and partly by a direct bond between the solid portions of the adsorbed layers. B.R.R.A.

296. **Measurements of Pore water Pressure in Silt and Clay.**

K. TERZAGHI. *Civil Engineering*, **13**, No. 1, 33, 1943.

The Bourdon gauge reacts immediately to a change in pressure, but is affected by temperature variations, and is not successful unless installed below the lowest piezometric level. In soils with low permeability, the installation of observation wells alters the hydrostatic pressure conditions, so that the readings obtained are not reliable. The Goldbeck cell, when used in clay, is liable to be rendered inaccurate by the fouling of the contact point, due to condensing moisture. A new pressure gauge has therefore been developed, consisting of a water-filled space, in communication with the pore water in the soil beneath a thin steel membrane whose deflections are measured by a Carlson strain meter. The two coils of the latter are immersed in castor oil, and the ratio of their electric resistances is determined above ground by a special Wheatstone bridge connected to the strain meter by a three-conductor "Tyrex" cable. The method of installing and sealing the gauge is given. One test in soft mud and three in clay are described, the dynamics of the last of the series being explained with reference to a system of perforated spring-supported pistons. B.R.R.A.

297. **Superposed Elastic and Viscous Behaviour.**

A. V. TOBOLSKY and R. D. ANDREWS. *J. Chem. Phys.*, **13**, 3, 1945.

The paper deals with stress-relaxation and creep in rubbers, on the general basis of the Eyring-Tobolsky theory. There are three separate temperature regions to be considered, (1) low temperature, in which the motion of chain segments is impeded by secondary forces between molecules, (2) intermediate temperature, characterised by a true elastic equilibrium, and (3) high-temperature, in which breaking down of the molecular network by oxidative scission of molecules, and further cross-linkage may occur simultaneously.

The experimental data, when analysed, reveal some important differences between natural and synthetic rubbers, and between pure and carbon-reinforced vulcanisates.

[It is not possible to do justice to this important paper in an abstract.]

L.R.G.T.

298. **Vertical Mounting for U-Tube Viscometers.**

TOWNSON and MERCER. *Journal Scientific Instr.*, **22**, 76, 1945.

Two plates held apart by distance pieces confine a plastic material which grips the limbs of the viscometer. The viscometer is positioned and the plastic baked hard. The complete unit may then be placed in the bath with the mounting resting on the cover. H.C.T.

299. **The Mechanical Structure of Viscous Elastic Continua: IX. Hysteresis in "Rheonome" Systems.**

H. UMSTÄTTER. *Kolloid Zeits.*, **105**, 182, 1943.

Flow curves show fewer reproducible measurements in the middle ranges of tangential pressure than when it has extremely low or extremely high values. It is obvious that this is a case of viscous elastic hysteresis, which cannot be accounted for entirely by errors in measurement, but it is a natural principle. It is shown in

the three-dimensional diagram of the Maxwell equation that these hysteresis loops are characterised by the absence of remanence (thixotropy) and coercivity (resistance to flow), which is only possible in liquids. The hysteresis loops of the solid body show a permanent deformation in their stress-strain diagrams, and have a definite inertia (resistance to flow). The result of this is that the fundamental properties of matter from the point of view of its mechanical structure can be traced back to three basic constants: shear elasticity, relaxation time, and limiting value of the layer thickness.

B.R.R.A.

300. **The Relationship of "Rheology" to "Strength of Materials"**.

A. C. VIVIAN. *Metallurgia*, **30**, 237, 1944.

This is a general discussion on rheology and its application in industrial problems.

B.R.R.A.

301. **Improvements in Lubricating Greases.**

M. W. WEBBER. *J. of Institute of Petroleum*, **31**, 89, 1945.

Research and development on lubricating greases proceed apace and industry now produces lubricants of uniform consistency, greater purity, wider temperature range and greater load capacity.

Further development will depend on the availability of new and improved ingredients and more efficient methods of test.

The greatest need of the industry for the further scientific development of lubricating greases, whatsoever their composition, is some practical method of determining their rheological properties in fundamental units, and some means of specifying the structure of greases in order to give some definition to such terms as "smooth," "non-fibrous," "short, medium and long fibre."

E.W.J.M.

302. **On the Flow of Liquids through Thin cracks.**

C. K. WENTWORTH. *Amer. J. Sci.*, **242**, 478, 1944.

The distinction between turbulent flow and laminar flow in water and other liquids had long been recognised. Among students of hydraulics laminar flow has been considered to take place down to indefinitely low hydraulic heads and velocities, with the consequence that rates of flow in a given opening are in direct linear proportion to hydraulic head. Experiments here reported show that in thin cracks and at low velocities, the rates of flow are diminished more rapidly than the hydraulic heads and that such diminution is a very systematic function of time. Under certain conditions, rates of flow, with head constant, have been reduced more than a thousand-fold, due to a process here interpreted as growth of adsorbed molecular films on the walls of the cracks. Within the limits of this behaviour and at the lower range of hydraulic flow, large and significant deviations from rates calculated by Darcy's law may, under certain conditions, take place.

B.R.R.A.

303. **The Thixotropy of Montmorillonite.**

H. G. F. WINKLER. *Kolloid Zeits.*, **105**, 29, 1943.

The thixotropic sol-gel conversion of suspensions of montmorillonite ("Tixoton") in aqueous solutions and in organic liquids was studied. A number of new experimental results were obtained. The convenient and easily determined "thixotropic limiting value" served as a measure of the degree of thixotropy. The relation between the solidification time and the thixotropic limiting value was discussed. It was decided, from the temperature factor of the thixotropic limiting value, which is expressed in Arrhenius' equation even for the dispersed particles concerned here, that the appearance of the thixotropy does not occur without "heat tone" (thermodynamics). This is, however, so small that it has not, as yet, been measured in practice. By different series of experiments the completely distinct thixotropic behaviour of

montmorillonite compared with that of other minerals, such as kaolinite, mica, feldspar, etc., was demonstrated. Experiments show that the internal crystalline swelling of montmorillonite and other factors, which are conditioned or produced by it (for instance, a particularly strong adsorption, etc.), are the causes of this singular behaviour. The internal crystalline swelling creates surface ratios which cannot easily be compared with those of other thixotropic minerals. The dependence of the degree of thixotropy on the grading was shown in "Tixoton" suspensions, whose particles were gradually dispersed ultrasonically. It was shown how the energy varies with the concentration of the systems, this change being necessary to begin the liquefaction of thixotropic gels.

B.R.R.A.