



BULLETIN OF THE
BRITISH RHEOLOGISTS' CLUB

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members of the Club
only.

CLUB NOTES

Membership.

The membership of the Club is now 95. This is most satisfactory for a year's run in wartime. Members have expressed an interest in a very wide range of materials. The principal of these may be classified as follows, the numbers in brackets indicating the number of interested members: Blood (2), Cellulose and paper (5), Ceramics and clays (9), Dairy products and margarine (7), Emulsions (6), Flour and doughs (3), Woodstuffs (general) (6), Glass (2), Glue and adhesives (5), Ink (7), Metals (5), Muscle (3), Oils and greases (12), Paints and similar materials (13), Pastes (3), Photographic materials (3), Plastics and resins (8), Rubber (7), Soils, silts and sediments (2), Starch (1), Tars, bitumens, road materials, etc. (13). It will be observed that some are interested in several of these categories, but others who have expressed interest in methods rather than materials do not appear in the classification.

Reprints of members papers.

Reprints of members papers are always welcome but it is not often possible for all members to be circulated with them. We are therefore most grateful to Dr. A.T. Green, Director of The British Refractories Research Association, for supplying all our members with copies of a recent paper on the rheology of clay by Mr. H.H. Macey, another of our members. These are being circulated with this bulletin.

Finance.

The finances of the Club are very satisfactory, the balance in hand at the end of the Club's first year (30th September) was £8. 8s. 7½d. This is in no small degree due to the generosity of the Institute of Physics, which has provided the necessary clerical work and duplicating paper without charge. The Club is most grateful. About half the members of the Club have so far overlooked the subscription reminder recently circulated. The annual subscription of 5s.0d. became due on 1st October, and the Treasurer invites co-operation in saving unnecessary administrative work in these difficult times by asking the members to let him have their remittances forthwith.

Report of the Third General Meeting.

Through the courtesy of the Director and Staff of The British Rubber Producers' Research Association, a most successful meeting was held at Welwyn Garden City, Herts., on Saturday, June 21st, 1941. About 40 members were present. Our only regret was that time was too short to do full justice to the most interesting programme provided by our hosts. The visit to the laboratories, although lasting for some hours, seemed only to touch the fringe of the wide field of rheological work being undertaken at Welwyn.

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In our discussion on thixotropy and allied phenomena we had no time to reach any very definite conclusions, but many interesting points of view were expressed and it would have been absurd to expect that we should fully clarify this very complex field in one short morning's meeting.

The meeting stood to show its respect for the late Professor H. Freundlich and his pioneer contribution to rheology, especially the study of thixotropic phenomena.

Contributions were read by Dr. Coppen, Mr. Harvey, Mr. Pryce Jones, Mr. Bilmes (on behalf of Mr. Broome), Dr. Mardles, and Dr. Lawrence, and in the absence of the contributors, by the Secretary on behalf of Dr. Lee, Mr. Macey and Dr. Arnold. In the general discussion which followed, the meeting was addressed by the President, Cmr. Goodeve, Mr. van Someren, Mr. Trask, Dr. Lawrence, Dr. Scott Blair and Dr. Lessing. Dr. Lessing proposed, for a subsequent meeting, that an exhibit of materials might be prepared to show various rheological properties, possibly arranged in accordance with the classificational scheme proposed by Cmr. Goodeve.

Following the meeting and before visiting the laboratories, the Club took lunch at the "Cherry Tree".

Encouragement from abroad.

Dr. M. Reiner, whose work on mathematical rheology will be wellknown to members of the Club, has sent us the following from Jerusalem: "I have told all disheartened people the story of how the British Rheologists' Club had a meeting in London on February 22nd, which had an 'excellent attendance'. I have just started a course of lectures on theoretical Rheology at the Physics department of the Hebrew University. At the last lecture I read them your letter. Please tell the British Rheologists' Club that our thoughts are with them. This is a message from the audience to my lectures and from me."

RHEOLOGY IN INDUSTRY - II

SOME RHEOLOGICAL PROBLEMS IN THE PLASTICS INDUSTRY, (Part I),

by W.G. Wearmouth, B.Sc., Ph.D., F.Inst.P.
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Rheology is becoming of increasing importance in the Plastics Industry. This is partly due to the fact that it provides extremely useful methods for tackling manufacturing problems and partly because fresh insight into the structural composition of plastics is provided by rheological measurements. The last point is an extremely valuable one to that large body of chemists who are continuously engaged in the synthesising of new members of this rapidly expanding family of synthetic materials.

It is fairly well known that the plastics industry is divided into two main branches - one concerned with the manufacture of the raw materials, and the other engaged in the fabrication of articles from these materials. Rheology is of interest to workers in both branches.

The raw materials of the plastics industry consist essentially of a synthetic resin or some allied plastic as base, mixed with (a) materials called plasticisers - to give strength and toughness and in many cases (b) fillers of all kinds to give special heat or shock resistance, or on occasions a cheaper product.

/Many

Many of these materials are produced in powder form, several are offered as solid sheets and films or as sheets in which the filler is in the form of layers of fabric or paper (because this method of 'laminating' as it is called gives a product of great strength and rigidity), and others are commercially available as rods and tubes, produced by the extrusion process.

In the manufacture of solid sheet one of three methods can be used. They are (1) by making the material into a dough which is then pressed into block form from which sheets are subsequently sliced (this process is often described as the celluloid technique) (2) by making the material into a powder which is then moulded by heat and pressure into sheet form in a heated steel mould, (the powder softens under heat, flows under pressure and so amalgamates producing the solid sheet) and (3) by taking a solution of the resin containing a suitable setting agent, pouring it into a sheet mould and allowing the mass to set gradually.

(1) Sliced Sheet. In sliced sheet it is essential to work the dough until it has the required stiffness of firmness, otherwise the load on the slicing knife will be too great. The firmness can be measured by means of a penetrometer or it can be estimated on a parallel plate plastometer; both methods are used. Adjustments to the firmness can be made by the addition of solvents to the material, or in other cases by simply raising the temperature of the block.

(2) Moulded Sheet. For the second method a powder of consistent flow properties must be available. Here again, the penetrometer, parallel plate plastometers and occasionally extrusion type plastometers are used for characterising the material. In the manufacturing processes high pressures (up to three tons per square inch) and high temperatures (often up to 175°C) are used for moulding the sheet. The plastometers therefore have to be worked under these conditions if they are to be of any service. This necessitates the development of a special technique and the literature is full of illustrations and descriptions of apparatus used in the determination of these flow properties. Many of the methods used are of an empirical character and they do not help greatly when problems arise such as the accurate comparison of the various materials used in the plastics industry. The A.S.T.M. have, for example, a proposed method of test in which a capillary type of plastometer is used. The flow which takes place under specified conditions is determined at a series of temperatures and the temperature required for a certain amount of flow is taken as the flow temperature.

Many attempts have been made (and some are still being actively pursued) to measure the flow characteristics of the plastic materials in conventional units.

Houwink has published some results on polystyrene. These proved that the material shows only quasi-flow, and possesses a finite 'yield value' over a definite range of temperatures. Other workers have confirmed this finding and a paper abstracted in this bulletin (Abstract No.71) deals with the same problem. Much more work is required to be done, however, before the rheologist can offer a complete solution to all the production problems arising in this branch of the industry.

(3) Cast Sheet. This method is employed for those plastic materials which polymerise. The polymerisation occasionally occurs at room temperature but in others it is necessary to maintain the temperature at 140°C - 160°C for some hours. From a rheological point of view the polymerising material should be fluid enough to pour into, and completely fill, the sheet mould. It must not become too viscous in the early stages of the poly-

merisation - bubbles are readily formed within the sheet if sufficient care is not taken - and viscometry checks on the polymerising material at various stages of the polymerisation have proved useful in this respect. The materials generally show true flow in the early stages of the polymerisation (governed by the relation $D = \frac{\tau}{\eta}$) but as polymerisation proceeds this changes to quasi-flow (governed by the relation $D = \frac{\tau^n}{\eta}$), where D is velocity gradient, τ is stress, η is viscosity and n a pure number. The point at which this change takes place is carefully controlled to ensure a uniform product.

(4) Laminated sheets. These, (as indicated above), are manufactured by impregnating sheets of fabric or paper with resin or other suitable plastic. The resin-coated sheets are then built up into sandwiches which are subsequently pressed together between heated steel plates and are thereby laminated. Giant impregnating machines are generally used for coating the paper or fabric and in these, the resin solution (usually a solution of plastic in a volatile liquid (industrial alcohol or water)) is pressed into the fabric by passing the dipped fabric through rotating metal rolls. The solution must therefore be of the correct viscosity for the fabric or paper to take up sufficient plastic during the time it is immersed in the solution. Some assistance in this matter is obtained by making the dipping chamber of suitable dimensions, but once these are fixed each batch of solution used should conform to an agreed specification for viscosity. The usual methods for this determination are used.

When the impregnated sheets are pressed up into solid sheet the resin flows under the action of the heat and pressure applied. The flow characteristics of the resin under these conditions are obviously important and should be maintained constant for successful production. The determination of these flow properties is complicated by the fact that most of the resins undergo further polymerisation under the pressing conditions. Indeed, with many of the resins used in this process, the final pressing is required so that the resin can be polymerised to its final infusible state.

This aspect will be dealt with later when we come to discuss the problems arising in the manufacture of plastic articles.

(5) Films. In the manufacture of films we have yet a further set of rheological problems. Most films are cast, and the process is a continuous one. Band or wheel machines are used. A concentrated solution of the plastic in solvent - in the form of a fairly thick dope - is spread out in a thin layer on to a continuously moving band; the coated band moves on through a series of heated chambers in which the volatile matter is driven off - and at the end of the outward journey the dried film of plastic is stripped off the band and wound on to moving rolls. The emptied band then returns to the starting point for a further coating of dope to be applied.

Since the process is continuous it is clear that the dope must be of a steady consistency and at a previously agreed concentration. If dilution is required to produce the approved consistency then the finished film will be down on thickness, since less solid plastic will be deposited in any given time. The dopes are, as we have seen, fairly thick and they are found to show only quasi-flow. Capillary type viscometers and sometimes the Couette type are used for controlling this required property in film manufacture. The influence of the viscosity of the dope on the strength of the resulting film is also a problem which has received attention in recent years. This is an important aspect since the product from film machines is used most extensively for photographic purposes (Cine film, etc.) and high tensile

/strengths

strengths for the film under rapidly changing stresses are therefore essential characteristics.

(6) Tubes and Rods in Plastics. These are generally made by the extrusion process, the plastic being pressed through a heated nozzle of the correct shape and size. Somewhat high pressures are used and temperatures of the order of 90°C to 150°C are employed according to the nature of the plastic being extruded. Incidentally, these extruders form excellent plastometers, the rate of flow under specified conditions giving a reliable guide to the extruding qualities of the plastic. Since these extrusions are continuous, it is essential to have most consistent materials for successful production. Plastometer tests are therefore taken to ensure uniformity, and generally speaking the data obtained together with a chemical inspection of the raw materials ensures satisfactory results.

It is of interest to note that some plastics can be similarly extruded but as they pass through the heating chamber polymerisation occurs and a completely polymerised product emerges from the orifice. These tubes and rods are infusible, that is, they will not soften when reheated, and this brings us to an important point which we have not mentioned hitherto: the difference between the two main groups of plastics. These groups are distinguished from each other by the fact that one of them contains materials which soften when heated, set on cooling, and can then be resoftened by further application of heat; the other will soften when heated but during the heating period polymerisation occurs causing the material to become hard and no fresh softening occurs if the material is cooled down and is subsequently reheated. The first type are the familiar thermoplastic materials, the second are called thermo-setting plastics.

Each of these groups contains a large number of members, so it is not surprising that there are many rheological problems in the plastics industry.

No mention has been made of those plastic materials used for lacquers and coating compositions since it is felt that the rheological problems of these materials are sufficiently well known not to require any further stressing.

Equally, it has not been thought convenient to discuss in this review the rheological problems found in plastic goods manufacture. These are many and varied and will be reviewed in Part II.

RHEOLOGY ABSTRACTS

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

49. Viscosities of homologous series at equal temperatures.
A.H. Nissan and A.E. Dunstan. J.Inst.Petroleum, 27, p.222, 1941.
The authors have plotted figures relating log viscosity in millipoises with log molecular volume for the homologous series n-paraffins and n-alkyl benzenes, omitting the first members. They conclude that log viscosity is connected more directly with molecular volume than with weight. The formula

$$\log \eta = A \log (\text{molecular volume}) + B$$

applies to a greater extent than the original

$$\log \eta = A (\text{molecular weight}) + B$$

proposed in 1914, when a wide range of members of homologous series

is considered. The molecular volume formula, however, is still far from being comprehensive. E.W.J.M.

50. The Viscosity of Russian and Rumanian lubricating oils at high pressure. R.B. Dow, J.S. McCartney and C.E. Fink. J.Inst.Petroleum, 27, p.301, 1941. The viscosities of four Russian and three Rumanian oils have been determined at temperatures of 100°, 130° and 210°F at various pressures up to 46,000 lb/in², in a modified form of the rolling-ball viscometer of Hersey.

The equation $\eta = \eta_0 e^{aP}$, where η_0 is the viscosity at constant temperature at atmospheric pressure, (a equals the pressure coefficient of viscosity), represents the data to a high degree of accuracy. E.W.J.M.

51. The Rheology of Clay. H.H. Macey. J.Sci.Inst., 18, p.159, 1941. The author reviews the rheology of clay-water systems with special reference to the structure of solid mixtures whose properties may be interpreted on the supposition that the surfaces of the clay particles repel one another, and thereby appear to be separated by water films. The difficulties not only of obtaining agreement between experimental results on any one sample, but also of correlating these results with those predicted on mathematical grounds, are discussed, together with a short account of some of the properties peculiar to clays.

/The confusion apparent in the results of the various workers discussed shows most clearly the need for precise definitions of rheological methods and terms/. H.C.T.

52. High Speed tension tests at elevated temperatures. A. Nadai and M.J. Manjoine. J.App.Mech., 8, A.77, 1941. Describes constant strain-rate testing machine for tensile tests over wide range of rates at various temperatures. Results for Al and Cu indicate continuous increase of yield stresses with strain rate. With Fe and Fe alloys resistance to deformation at given speed exhibits maximum and minimum at certain temperatures. This maximum known as "blue brittleness". A large part of the paper is mathematical and concerned with possibility of calculating the shape of the broken ends of the test-piece. Shows Bingham formula inapplicable, and proposes "speed law" of form $u = as^n$, where u = rate of strain, s = stress, and a and n are constants. The shape of the broken ends varies with the value of n .

/The formula $u = as^n$ is an empirical method of obtaining, with variation of n a gradual transition from the properties of a viscous liquid to those of a brittle solid. The former is given when $n = 1$, and the latter when n is infinite, for, in this case, the rate of strain or of flow suddenly becomes infinite when $s = 1$. It is interesting to compare formula of Scott Blair and Coppen, Nature, 146, p.840, 1940, and that of de Bruyne, Proc. Phys. Soc., 53, p.251, 1941/. H.H.M.

53. Colloid chemistry in ceramics. E.A. Hauser. J.Amer.Ceram. Soc., 24, p.179, 1941. The Edward Orton, Jr. Memorial Lecture for 1941. A description of the X-ray structure of the various clay minerals and a discussion of colloidal properties based thereon. A.T.G.

54. Fundamental study of clay: II, Mechanism of deflocculation in the clay water system. A.L. Johnson and F.H. Norton. J.Amer. Ceram. Soc., 24, p.189, 1941. The effect of bases, basic salts, neutral salts, and acids on the viscosity of clay slips cleaned as described in Part I of this study is shown. From this data, a fundamental theory of deflocculation is built up, based on the fact that deflocculation requires the presence of OH anions and monovalent cations. The influence on the viscosity of small traces of soluble salts or adsorbed ions, which are present in

commercial clays, is discussed. It is also shown why sodium silicate or carbonate works more satisfactorily than sodium hydroxide in the deflocculation of commercial casting slips. A.T.G.

55. Suspension media for float and sink concentration. Anon. Mine Quarry, 6, p.107, 1941. As part of a general discussion on flotation, the effect of particle shape on the apparent viscosity of quartz suspensions is shown graphically. The apparent viscosity of a suspension of angular quartz grains is considerably higher than that of a suspension of rounded quartz grains of the same concentration. This is due to the rolling of the rounded grains over one another. A.T.G.

56. Notes on the Softening of Coal. C.A. Seyler. J.Inst.Fuel, 14, p.195, 1941. General discussion of rheological properties of coal at high temperatures. A.T.G.

57. Non-ferrous physical metallurgy; present status of metallurgical thought on plastic deformation, strain-hardening and recrystallation, copper-gas reactions, fatigue and magnesium alloys. R.M. Brick and A. Phillips. Mining and Met., 22, p.87, 1941. A good review of recent work on the plastic deformation and strain-hardening of metal crystals. A.T.G.

58. Time and temperature effects in the formation of colloidal dispersions. P.G. Nutting. J.Wash.Acad.Sci., 31, p.41, 1941. The behaviour of montmorillonite clays in acids of various concentrations and with various ratios of acid to clay have been investigated. Solutions in dilute HCl at 28° and 90°C. may contain more than twice as much SiO₂ as a saturated solution of SiO₂ in water. At 90° equilibrium is reached in about 4 days; at 28° it is not reached after 128 days. The bearing of these results on the formation of clay colloids in rock cavities and soils is discussed. A.T.G.

59. The Viscosity, Protein distribution and gold number of the antenatal and postnatal secretions of the human mammary gland. H. Waller, R. Aschaffenburg and M.W. Grant. Biochem.J., 35, p.272, 1941. From the rheological point of view, the interest in this paper lies in the fact that these secretions, which are non-Newtonian fluids often approximating closely to Newtonian behaviour, show a viscosity (at an arbitrary stress) which is highly correlated with the other properties measured. The log of the kinematic viscosity is linearly related to total nitrogen and to gold number.

Clinically, any of these properties gives a useful criterion for the end of the colostrum (abnormal milk) period after parturition but viscosity anomalies do not account for lactation difficulties. (See next Abstract). G.W.S.B.

60. The determination of viscosity of human milks and pre-natal secretions. G.W. Scott Blair. Biochem.J., 35, p.627, 1941. A U-tube type of viscometer is described for measuring viscosity and change of viscosity with stress of small samples of the secretions. It is concluded that viscosity anomalies are of the non-Newtonian fluid type with no tendency to yield-value. Lactation difficulties are unlikely to be due to rheological anomalies. Author.

61. Variability in physical properties of Wisconsin butter. K.G. Weckel. Nat.Butter & Cheese J., 30, p.63, 1939. Weckel measures the force necessary to crush cubes of butter 2.5 x 2.5 x 1. also weight required to draw a standard spatula through butter cylinders at 44°C: also time taken for a "beam" of butter to sag by known amounts when supported at its ends. Weckel claims that these empirical rheological tests give useful information relating

to quality of butter.

G.W.S.B.

62. Struktur der Butter und des Butterfettes (Structure of butter and butter fat). W. Mohr. Molkerei Zeit, 53, p.2335, 1939. Discusses thixotropy and firmness of butter. Firmness is measured by resistance offered to cutting wire by a standard cube. Microphotos showing fat structure are given, taken by polarised and non-polarised light. G.W.S.B.

63. Emmental cheese body texture. G. Koestler. Milchzeit, 66, pp.83, 87, 93, 100, 1940. An extension of the work already abstracted (no.18).

[Little new information is given.]

G.W.S.B.

64. Improvement in the viscosity of pasteurized cream through subsequent heat treatment. H.F. Wiese, J.H. Nair & R.S. Fleming. J. Dairy Res., 22, p.875, 1939. The viscosity of cream can be increased by various heating and cooling processes (Rebodying). This paper is a study of these phenomena which is ascribed to the activity of the surface membranes on the fat globules. G.W.S.B.

65. Some factors affecting the body of market cream. F.M. Skelton and E.O. Herreid. J. Dairy Res., 24, p.289, 1941. Viscosities of cream are measured in an orifice viscometer (the Borden Body Flow Meter). Effects of pasteurisation are especially studied.

[No adequate description of the viscometer is given] G.W.S.B.

66. Consistency of cheese curd at the pitching point and its bearing on the firmness and quality of the finished cheese. G.W. Scott Blair and F.M.V. Coppen. J. Dairy Res., 12, p.44, 1941.

A preliminary study of the effects of varying pitching consistency and rate of scald on the physical and chemical properties of cheddar cheese and in the firmness of the cheese as judged by cheese-makers, bakers and others. G.W. Scott Blair, F.M.V. Coppen and D.V. Dearden. Ibid, p.170. These two papers describe a continuation of the work already abstracted (No.17). The consistency of curd at the pitching point is measured as described in the earlier paper on a large number of cheeses in several factories and compared with the subjective (handling) judgments of skilled cheese-makers. The smallest differences which can be judged by handling such materials correspond to those found for elastic bodies and are considerably smaller than those for viscous materials, from which it is inferred that the consistency at pitching is judged mainly from the elastic properties of the curd. In the later paper, a large number of rheological and other physical properties of cheese made at different pitching consistencies were measured and the data compared with subjective judgments. The cheese-makers, who find remarkable difficulty in judging specific rheological properties such as firmness, give judgments which tend to fall together, as do also bakers (used to similar tests on different materials) and subjects having no special experience. Of these three groups, the bakers' results tend to fall between the cheese experts' and inexperience. A ball-compressor apparatus is described for measuring firmness and springiness of cheese. G.W.S.B.

67. Speeds Viscosity Measurement in Capillary Type Viscometer. E.H. Zeitfrichs. National Petroleum News, 38, R 121 - R 124, 1941. An overflow trap to eliminate errors in volume is placed at the lower end. Detailed descriptions, dimensions, formulae for correction of kinetic energy and drainage errors are given, as well as a rigid metal support recommended. Five sizes cover a range from 1 to 1000 centistokes.

[The overflow trap is also a trap for foreign matter] L.A.S.

68. Mechanical Properties of Monolayers. S. Bresler, M. Judin and D. Talmud. Acta Physicochimica U.S.S.R., 14, pp. 71-85, 1941. Monolayers subjected to polymerisation and polycondensation exhibit different mechanical properties according to the type of reaction which takes place. Annular films, stressed between a disc and a ring, behaved like a perfectly elastic solid, or like a non-elastic viscous liquid or like an intermediate type of material. L.A.S.

69. Relation between rate of crystallisation and viscosity of glasses. A. Leontjewa. Acta Physicochimica U.S.S.R., 14, p.245, 1941. The rate of crystallisation was measured at different temperatures and correlated to viscosity temperature curves. A simple relation exists between rate of crystallisation and reciprocal viscosity. L.A.S.

70. Plant Waxes. L. Ivanovszki. Oil and Colour Trade Journal, 98, p.944, 1940; 99, pp. 98 - 102, p.140, pp. 174 - 175, 1941. Deals with viscosity on page 98 and 175, 1941. The viscosity curves of several waxes have been measured between 80 and 120°C with a Steiner Viscometer. The value of viscosity is emphasized as as a discriminating property of waxes both before and after refining or other treatment. L.A.S.

71. The flow properties of thermoplastics. I. W.G. Wearmouth and J.S. Small. British Plastics, May, 1941. This is the first of a series of articles by these authors. Measurements of the yield-value for a number of the more common industrial plastics are described and the variation of this value with temperature is shown by means of graphs. Scott's formula is used for calculating the yield value from the 'limiting height' reached when a pellet is compressed between the plates of a parallel plate plastometer. Two types of materials were observed: (1) The synthetic type, which shows a sharp decrease in yield value over a very narrow temperature range - called "the softening range". Materials like polymerised styrene are of this type. (2) The natural type, like cellulose acetate plastics, which show only a gradual change in yield value as the temperature is raised. The "softening range" is very large in these cases. W.G.W.

72. Plasticity of Moulding Compounds. R. Burns. Modern Plastics, May, 1941. (A lecture delivered before the A.S.T.M. in June 1940.) This article gives a very brief account of a simple empirical method for determining the "plasticity" of moulding compounds. The apparatus used is made up of a solid metal bolster surrounding a split cone containing machined circular orifices. A circular cavity is left above the cone and also inside the bolster, into which the test powder can be placed. The whole arrangement is heated to the test temperature and a similarly heated plunger is then pressed down on to the powder so forcing the heated powder into the above mentioned circular orifices. Each of these has a definite diameter (ranging from very fine to large capillaries) and the amount of flow in each of these is measured in inches. All the products of the length of flow and the inverse of the diameter of the orifice for all the apertures are added together and the result is called the plasticity figure. The method ingeniously takes into account the difficulty with which some of these moulding materials flow into very narrow orifices, and an average figure for the flow is therefore obtained. It is claimed that the method provides a useful check on any batch-to-batch variations in the flow of these materials. It is used for both thermoplastic and thermosetting materials, and a short note is added on the measurable effect produced on the flow of these materials through absorption of atmospheric moisture. W.G.W.

73. Supercooled silicates and their importance in considerations of the liquid state. E. Preston. J.Phys.Soc., 53, p.568, 1941. A study of the properties of crystallisation,

/viscosity

viscosity, electrical conductivity and surface tension shows that silicate glasses are supercooled liquids and may be regarded as solutions, the constituents of which are associated to a greater or lesser degree, depending on composition and temperature. Recent researches on the structure of glasses by X-ray methods indicate that it is typical of the liquid state. Glass at room temperature possesses a static structure as opposed to the dynamic ever-changing configuration of the particles of a normal liquid, and on this account simple glasses may prove to be of great value in the further elucidation and the provision of an adequate theory of the structure of liquids.

[A comprehensive paper of considerable general interest].
L.R.G.T.

74. Elastic and thermoelastic properties of rubberlike materials. E. Guth and H.M. James. Ind.Eng.Chem., 33, p.624, 1941. The statistical theory of rubber elasticity is treated generally and extended to cover the case of a molecular network. The following relation between tension (Z) and length (L) is derived:

$$Z = \text{const.} (L - 1/L^2)$$

and found to agree with the experimental stress-strain relationships for rubber both in extension and compression.

[The treatment is too sketchy to be convincing. In the evaluation of the constant in the above equation it is not even clear what the symbols used are intended to represent]. L.R.G.T.

75. Viscosity of chocolate. J. Stanley. Ind.Eng.Chem. (Anal.Ed.), 13, p.398, 1941. The theory and technique of the MacMichael (rotating cylinder) viscometer as applied to chocolate are examined, and a standard technique is described which embraces the whole range of viscosities encountered. The factors influencing the viscosity, i.e. cocoa butter, lecithin, moisture, fineness, and temperature, are discussed. Rheograms are presented which lead to a better understanding of practical properties such as "gumminess" and "coverage".
L.R.G.T.

76. Structure and dynamics of liquids. W.E. Roseveare, R.E. Powell and H. Eyring. J.App.Phys. 12, p.669, 1941. This paper rehearses and develops the view that the characteristic properties of liquids can be explained by regarding the liquid as a mixture of molecules and "holes", i.e. unoccupied but possible equilibrium positions for molecules.

[Rough but encouraging agreement with experiment is obtained for viscosity, diffusion, latent heat of fusion, expansion on fusion and on further heating, optical anisotropy due to flow and for the dependance of some of these properties on concentration in mixtures].
P.W.

77. Correlation between elastic moduli and viscosities of liquids and plastics. A. Gemant. J.App.Phys., 12, p.680, 1941. The author gives theoretical reasons for supposing that the following relation might hold approximately between the bulk modulus K and the kinematic viscosity μ : $MA = K T \rho (\log \mu + B)$ where M is molecular weight, T absolute temperature, ρ density and A, B are functions of certain molecular constants.

[Rough but encouraging agreement with experiment is obtained for heptane, some petroleum fractions (see Abstract 38), polyvinyl chlorides and some glasses].
P.W.

78. Relaxation of metals at high temperatures. W.E. Trumper. J.App.Phys., 12, p.248, 1941. The rheological interest of this paper lies in a special method of using an extensometer which enables creep tests on metals to be completed in one week instead

of 12 to 24 weeks as formerly. The innovation consists in automatically diminishing and recording the applied stress so that the extension remains constant during an experiment. The creep is thus balanced out by reducing the recoverable component of the total strain by a known amount.

Data for comparison of these tests with those of the former type are scanty but, as far as they go, satisfactory.
P.W.

79. X-ray study of the changes which occur in aluminium during the process of fatiguing. R.G. Spencer and J.W. Marshall. J.ApppPhys., 12, p.191, 1941. No changes can be detected by X-rays when the specimen is fatigued below its endurance limit. When the stresses exceed the endurance limit, changes can only be detected immediately before rupture. Since the earlier cycles of stress must produce some permanent change, this change must be in the amorphous intercrystalline material if it is to remain undetected by X-rays. Just before rupture the photographs shew evidence of rotation, strain and rupture of the crystallites.

80. Theory of the plastic properties of solids. F. Seitz and T.A. Read. J.App.Phys., 12, pp. 470 and 538, 1941. These two papers are a continuation of those mentioned in Abstract 41 and should be consulted in full.

81. General theory of three-dimensional consolidation. M.A. Biot. J.App.Phys., 12, p.155, 1941. Consolidation settlement of a soil with an impervious top surface. M.A. Biot and F.M. Clinigan. J.App.Phys., 12, p.578, 1941. Consolidation settlement under a rectangular load distribution. M.A. Biot. J.App.Phys., 12, p.426, 1941. Assuming the soil to be a perfectly elastic open-work structure permeated by an incompressible liquid, these authors derive and solve equations for its behaviour under loads of various types. These papers should be consulted in full. P.W.

82. Frictional Phenomena. A. Gemant. I, General. J.App.Phys., 12, p.530, 1941. II A, Gases. J.App.Phys., 12, p.626, 1941. These papers should be consulted in full. P.W.

in Attention is drawn to the following papers which may be of interest to rheologists working in special fields. P.W.

83. RUBBER. Special rubber number of J.App.Phys., Jan.1941, vol.12, pp.2 - 45. Of more rheological interest are: Physical characteristics of synthetic rubbers. J.N. Street and J.H. Dillon. p.45. X-ray study of the proportion of crystalline amorphous components in stretched rubber. J.E. Field. p.23.

84. Thermoplastic behaviour of linear and three-dimensional polymers. S.S. Kistler. J.App.Phys., 11, p.769, 1940.

85. Some relations of flow and physical properties with formulation in cellulose acetate plastics. W.E. Gloor. J.App.Phys., 12, p.420, 1941. This title means that properties are studied as a function of composition.

86. Physical Aspects of boundary lubrication. O. Beeck. J.App.Phys., 12, p.512, 1941.

87. PHOTO-ELASTICITY. Special Photoelasticity number of J.App.Phys., Aug. 1941, vol. 12, pp.583 - 652.

88. The "supply" of physicists (including rheologists; in the U.S.A.). J.App.Phys. 12, p.655, 1941. This Editorial article analyses the distribution of the special fields of 5045 physicists registered on the (U.S.) National Roster of Scientific and Specialised Personnel (equivalent to our Central Register). Since registration is voluntary and the roster has only been open for one year the data are only a sample. Rheology appears as a sub-class under "Borderline Fields" but there is a main class called "Materials, testing and properties of" which is mainly rheological. Figures in brackets are numbers of physicists giving a specified branch as their main interest. Unbracketed figures include all those who gave the specified branch as their first, second or third preference. Metallurgy 151 (55); Elasticity 71 (37); Synthetic materials 54 (15); Rubber 51 (28); Textiles & paper 50 (26); Building materials 47 (12); RHEOLOGY 45 (18); Glass 33 (21); Soil 33 (10); Colloids 33 (8). P.W.
