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THE BRITISH SOCIETY OF RHEOLOGY

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RHEOLOGY IN MECHANICAL ENGINEERING

During the late war the Department of Scientific and Industrial Research set up a Committee under the Chairmanship of Dr. (now Sir) Henry L. Guy, F.R.S. to consider in detail how the essential requirements of research in Mechanical Engineering problems could be provided and, on the basis of their report, the Mechanical Engineering Research Laboratory has been brought into being. This Laboratory is one of the stations of the Department of Scientific and Industrial Research and is situated at East Kilbride, a new town which is being built in Lanarkshire. Responsibility has been assumed for a large part of the research originally undertaken in the Engineering Division of the National Physical Laboratory and a number of former members of the staff of that division were transferred to East Kilbride to form the nucleus of the new organization. The work of the Laboratory is organized in seven divisions as follows:—

Properties and Strength of Materials.
Mechanics of Solids, Stress Analysis, and Vibration.
Mechanics of Fluids, including Hydraulic Machinery.
Lubrication, Wear, and Corrosion.
Mechanisms and Engineering Metrology.
Mechanics of Formation and Machine Shaping of Materials.
Heat Transfer and Applied Thermodynamics.

The Director of the Laboratory has kindly agreed to the Society holding a conference at M.E.R.L. to discuss Rheology in Mechanical Engineering and has generously placed full facilities at our disposal. The Conference will extend from Thursday, 10th to Saturday 12th June, 1954. The work of the divisions that is of particular interest to rheologists will be described in formal papers by Heads of Divisions or by members of their staff:

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|------------------|--|
| Barwell, F. T. | Lubrication from the rheological standpoint. |
| Bishop, J. F. W. | The relation of certain properties of metals to their crystal structure. |
| Johnson, A. E. | Some aspects of the behaviour of metals under complex stresses at high temperatures. |
| LeFevre, E. J. | Some developments in the theory of viscosity. |
| Pugh, H. Ll. D. | Current problems and experiments on time independent plastic deformation. |
| Robinson, W. J. | Some fluid motion problems. |

A number of invited papers will also be presented and arrangements are being made for members to see the research being undertaken in the Laboratory as a whole.

A.A.M.

COMMENT

In his recent book "Science and Common Sense",⁽¹⁾ Conant goes some way towards correcting the impression frequently conveyed by our most brilliant popularizers of scientific philosophy that science is primarily a theoretical activity indulged in by a small number of mathematicians of extraordinary genius whom the ordinary man may worship but cannot hope to follow. He distinguishes between science as a system of organized knowledge and science as a process of discovery. It is the latter aspect with which he is primarily concerned. Science is defined as "an interconnected series of concepts and conceptual schemes that have developed as a result of experimentation and observation and are fruitful of further experimentation and observation." He illustrates his theme by numerous historical examples. Among these the story of the discovery of oxygen and its role in combustion is outstanding, and is well worth reading for its own sake. One sees here how even the greatest scientists not infrequently make mistakes. They suffer from prejudices, and indulge in personal animosities like the rest of us. Avogadro's concept that equal volumes of gases (in a standard state) contain equal numbers of molecules was not accepted by the leading chemists of his day, and as a result, the development of the atomic theory was held up for half a century. Why? Primarily because chemists could not believe that two atoms of hydrogen, or of oxygen, could unite to form a molecule.

A more recent example of opposition to the introduction of a new concept, particularly when this arises from work in a different field, is discussed by Flory in his book on polymer chemistry.⁽²⁾ As early as 1863 Laureño succeeded in synthesizing short-chain condensation polymers. He recognized a relation between molecular weight and viscosity, and clearly envisaged the possibility of the formation of what we now call macromolecules. Thereafter, in spite of accumulating evidence, chemists failed to recognize that long-chain products, of indefinite molecular weight, could exist, and it was only with the work of Staudinger, around 1920, that the concept began to bear fruit. The chief reason for the delay, according to Flory, was the obsession of organic chemists with purity, a pure substance being defined as one consisting exclusively of a single molecular component of precise structure. Colloidal states were generally (quite correctly) attributed to molecular aggregation; that they might also arise from a particular type of primary valence structure did not fit in with text-book ideas. The evidence derived from the study of solution properties (viscosity, osmotic pressure, etc.), being imperfectly understood, was largely discounted.

One may perhaps be permitted to draw the conclusion that the attitude of exclusiveness engendered by a proper pride in the methods and discipline of one's own subject may be carried too far, to the detriment of the process of cross-fertilization from which new scientific concepts so frequently germinate. Rheology in particular draws widely on knowledge and experience gained in many other fields of activity—physics, chemistry, biology, engineering and a variety of industrial technologies—and it has always been a primary concern of our Society to bring together workers in all these fields. Rheologists may thus be well placed to take advantage of new and helpful concepts as they arise, for it is only by the development of new concepts that a science remains vigorous and alive.

L. R. G. TRELOAR.

- (1). Science and Common Sense. J. B. Conant. *Oxford*, 1951.
- (2). Principles of Polymer Chemistry. P. J. Flory. *Cornell*, 1953.

**The effect of some physical and rheological properties
on the friction and lubrication of solids**

D. TABOR

(Research Laboratory on the Physics and Chemistry of Surfaces, Cambridge.)

When metals are placed together they generally touch only at their high spots. At these points of real contact the local pressures are usually sufficient to produce plastic flow. By a process of cold welding strong junctions are formed at these regions and the force to shear them is primarily the source of the frictional resistance. This mechanism applies to other solids but the detailed behaviour depends on the physical and rheological properties of the materials.

With metals the deformation at the asperities is primarily plastic and the area of contact is proportional to the load and independent of the size of the surfaces. This explains the two "classic" laws of friction, that the friction is proportional to the load and independent of the size of the bodies. If, however, the metal surfaces are scrupulously freed of oxide films these laws of friction no longer apply. Because the surfaces are clean they adhere strongly whenever they touch and the sliding process itself produces a very marked growth of the junctions. The friction is phenomenally high and the surface damage heavy. On the other hand oxide films which retain their integrity at the interface greatly reduce the amount of metallic welding so that the friction and surface damage may be greatly diminished.

With non-metals such as long-chain polymers or plastics the friction may still be explained in terms of an adhesion mechanism but here the deformation properties are dependent on the load, the specimen size, and the time of loading. These effects are reflected in the frictional behaviour.

With solids which are normally considered to be brittle it is found that the local pressures around the individual regions of contact are sufficient to prevent brittle fracture and there is considerable *plastic* flow at the interface. As a result although some surface fragmentation may occur the sliding process is dominated by *plastic* deformation of the surface layers. Indeed a detailed study suggests that the frictional behaviour of brittle materials is primarily due, as with metals, to local plastic flow and to strong adhesion at the sliding interface.

The importance of taking into account the high pressures existing at the points of real contact is also shown in considering the behaviour of surfaces sliding under conditions of boundary lubrication. With a good lubricant the greater part of the frictional force is expended in shearing the lubricant film itself. One might therefore expect the friction of a lubricated soft metal (e.g. tin) to be enormously greater than that of a lubricated hard metal (e.g. tool steel) since the area of real contact, i.e. the area of the oil film being sheared, may be a hundred times greater for the tin. In fact the friction is little greater. This difficulty is resolved when it is realized that the lubricant is subjected to pressures which approach the yield pressure or hardness of the metal and these have a profound effect on the rheological properties of the lubricant film. As the work of Bridgman shows the shear strength of hydrocarbons increases in an approximately linear fashion with the pressure. As a result the friction of lubricated surfaces will be almost independent of their hardness.

Paper read 26th February, 1954.

Friction and surface deformation of fibres

H. G. HOWELL

(British Rayon Research Association, Manchester.)

The simple friction-load relation expressed by Amontons's law $F = \mu R$ is not applicable to fibres but with these materials a satisfactory expression is found empirically to be $F = aR^n$ where a and n are constants for a given pair of contacting surfaces, n being less than unity. According to the Bowden-Tabor theory of friction the final area

of contact of the surface asperities is determined by plastic flow and if it be assumed that in the fibre case the area of the contacts is determined by some degree of elastic deformation, the theory can account for the fractional value of the index n . In the case of elastic deformation n may be $2/3$ or higher, and in all cases of plastic deformation, $n = 1$ so that the value of n may provide information about the surface properties.

It is seen that the form $F = aR^n$ is more general than Amontons's law, including it as it does, for $n = 1$. An idealised model of contacting surfaces having elastic asperities shows that a physical interpretation can be given of the coefficient a in terms of size, number, distribution and elastic properties of the asperities.

Experimental studies of contacting areas have been made. In this work it is necessary to distinguish between "real" area of contact as measured by frictional forces, "geometrical" or "elastic" area as used in the Hertz theory and "apparent" or "optical" area as measured in these studies. These show that any simple model of ideally elastic asperities must be modified to take into account large delayed-elastic and irreversible deformations, i.e. their visco-elastic properties must be taken into account.

Paper read 26th February, 1954.

The frictional behaviour of anodic films on aluminium surfaces

K. H. R. WRIGHT

(Lubrication Division, M.E.R.L., Thorntonhall, Glasgow.)

The extent to which an oxide film can protect a metal surface from frictional damage depends greatly upon the relative rheological properties of the metal and the oxide film. Normally, soft films on hard substrates give low friction and relatively little surface damage. Aluminium oxide is hard and thin natural oxide films on aluminium surfaces offer little protection as they are easily ruptured at the lightest loads. Some improvement can be obtained by artificially increasing the thickness of the oxide film by an anodising treatment. A study has been made of the frictional behaviour of such films and it has been found that, with increasing load, the films first fail in tension owing to the self-imposed frictional force developed on sliding, and then as the deformation increases gross disintegration of the oxide surface occurs.

The frictional properties of the films show a marked dependence on the surface roughness, and provide an interesting example of the form of friction postulated by Bickerman. It has been observed that the porosity of certain types of anodic films can play, in the presence of lubricants, an important role in reducing the coefficient of friction.

Paper read 26th February, 1954.

Some aspects of the behaviour of metals under complex stresses at high temperatures

A. E. JOHNSON

(Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.)

In engineering power plant, many cases occur where metallic materials are under operating conditions in which structural parts are subject to complex stresses at high temperatures, causing plastic strain and creep either under steady stress conditions, or under conditions of relaxation, as in the pipe flange. Additionally, cases occur where owing to the conditions of operation, the imposed complex stress system operating upon a particular element of the part may be subject to periodical change.

Designers dealing with problems of the above type have been most inadequately supplied with basic data, and in general, improvisation has had to be made on the basis of doubtfully valid theory used in conjunction with such data as was available under simple stress systems.

To rectify this position a comprehensive research was commenced some years ago under the auspices of M.E.R.O., in which a detailed examination has and is being made of the complex stress creep, plastic strain and relaxation properties of several metal and metallic alloys, which, while being typical practical engineering materials, are different

in their basic structures. The temperature range examined for each of these materials has been in each case chosen as the practical temperature range of use at high temperatures in actual engineering practice.

The current paper is a record of the progress made in this research up to the present time, describes briefly some of the equipment used in the research, and indicates the conclusions reached in such aspects of the work as are substantially complete.

The materials principally used have been an 0.17% C steel at 350 and 450°C, an aluminium alloy at 150 and 200°C, and a magnesium alloy at 20 and 50°C. Additionally, for specific purposes, use has been made of other materials, such as 0.5% Mo steel, and commercially pure copper. All these materials except the 0.5% Mo steel, were in high macroscopically isotropic condition as regards creep and plastic strain properties.

In the matter of complex stress creep under simple loading conditions, it has been shown that for all the materials concerned, and at all temperatures, the creep rate stress relations lie within two categories, according to the stress level concerned.

In both categories the materials appear to follow the Mises criterion of plastic strain. At low and moderate stresses the materials obey simple St. Venant Mises stress creep rate relations in which the exponent of the strain energy term is much the same for all materials, and complete isotropy under creep is preserved. At higher stresses, anisotropy arises, which is of the same type in all cases except one, and it becomes necessary to use a generalised St. Venant Mises equation in which the strain energy function is more complex. Over restricted ranges of stress and time all creep curves are geometrically similar for a given material, and the time dependence of creep is the same.

For combined stress creep under general loading conditions, it appears possible to represent the data obtained over restricted ranges by diminishing the strain energy term of the St. Venant Mises equation by a function of the integrated creep strain previously incurred.

It appears that under these conditions the time dependence of creep of the virgin material is maintained, and anisotropy, where it occurs, is of the same type as in virgin material, and anisotropy coefficients under a given stress system are those under that system for the virgin material.

Complex stress plastic strain tests up to 2% plastic strain, and under simple loading conditions only, on the magnesium alloy, have shown that up to 100°C, a simple St. Venant Mises equation represents the stress plastic strain relations, and isotropy is preserved. At 150°C anisotropy occurs in which the anisotropy coefficients are apparently linear functions of the stress system imposed.

Corresponding tests on the aluminium alloy under both simple and general loading conditions have indicated a close similarity of relations for simple and general loading. Anisotropy arose in this material at relatively low stresses involving, however, the use of one anisotropy coefficient only. This coefficient for a given stress system remained constant throughout the stress range for simple loading, but in the general loading case assumed the value corresponding to the current stress ratio.

Complex stress relaxation tests have not yet commenced, but a machine has been designed to carry out relaxation tests at high temperatures under combined tension and torsion stresses.

The criterion of fracture under complex stress creep conditions has been examined for 0.5% Mo steel at 550°C and for pure copper at 250°C, particularly in regard to the Siegfried theory of complex stress fracture. A strong indication has been given that whatever the physical features of the fracture, the life period under creep conditions is a function of the maximum principal stress.

In the case of short time complex stress fracture, the aluminium alloy appeared to obey a criterion between the shear strain energy and maximum shear stress criteria, and certainly bore no relation to the maximum principal stress.

An examination is in progress of the relations in pure torsion between creep, recovery and relaxation, and this involved the design of a torsion creep machine capable of measuring rates of order 10^{-9} /hr.

Some information has been gathered concerning the time and temperature depen-

dence of creep, which appears to indicate that none of the current theories of creep and recovery are adequate, apart from the Nowick, Kauzman and Feltham theories of secondary creep, which appear to represent the secondary creep rates measured quite well. These results, however, are incidental to the main purpose of the research.

It is intended to investigate the above-mentioned metals and alloys under complex stress fatigue conditions at high temperatures, with particular regard to combined creep and fatigue failures. For this purpose a combined tension and torsion fatigue machine for high temperatures is being constructed.

*Paper to be read at the Conference on "Rheology in Mechanical Engineering,"
10th-12th June, 1954.*

Lubrication from the rheological standpoint

F. T. BARWELL

(Lubrication Division, M.E.R.L., Thorntonhall, Glasgow.)

Lubrication may be defined as the reduction of friction and wear between running surfaces by interposing a substance which offers resistance to the normal force pressing the surfaces into contact and yet which is capable of being sheared easily in a tangential direction. This is exemplified by the use of layer lattice materials such as graphite or molybdenum disulphide which present planes on which shear may easily occur but which are resistant to compression at right angles thereto.

The ideal state of affairs, wherein the surfaces are separated by a fluid in which sufficient pressure is generated to balance the applied load, was first dealt with analytically by Osborne Reynolds in 1886. It is surprising how little the considerable volume of theoretical and experimental work in the intervening period has added to our understanding of the subject. Reynolds' analysis was based on the assumption that fluids were Newtonian. In the extreme cases of modern practice, consideration must be given to the extent to which the mineral oils used for lubrication depart from this condition. The shear rates in a modern bearing may approach two million reciprocal seconds but the evidence that shear rates of this order lead to a change in the viscosity of mineral oils is far from being conclusive. A more important consideration is the change of viscosity with pressure, an increase in pressure from 1 to 1,000 atmospheres may lead to a fifteen fold increase in viscosity. Under conditions of intense loading such as are met with in certain types of gears, this factor may well explain freedom from wear which is surprising from the standpoint of the simple hydrodynamic theory. Where bearings are so heavily loaded as to depart from the friction velocity relationships predictable from hydrodynamic theory, pressure viscosity effects may again become important. When bearings are required to operate at high speed, the limit of laminar flow may be reached and inertia effects such as Taylor vortices become important.

Lubricating greases have been studied from a rheological point of view mainly as a method of rationalizing quality control. Little attention has heretofore been given as to whether or not such properties as yield value, plastic viscosity etc., have any functional significance. Modifying Reynolds' equations by substituting a Bingham solid for a Newtonian fluid reveals that the important quality is the plastic viscosity. The existence of a yield value leads to the presence of unsheared regions within the running bearing.

Further understanding of the mechanism of wear is dependent among other things on a clear picture of the rheological behaviour of the material in surface region of the components suffering damage. For example, damage to the surfaces may occur by the extrusion of metal through cleavages in the oxide film as a result of contact welding or by ploughing of the softer material by adventitious hard particles present between the surfaces. In considering the wear properties of steel for example hardness of the bulk material appears to be of less importance than that of the softer phases of the micro-structure.

*Paper to be read at the Conference on "Rheology in Mechanical Engineering,"
10th-12th June, 1954.*

CORRESPONDENCE

To the Editor,
The British Society of Rheologists' Bulletin.

Dear Sir,

In a paper of mine published in July, 1949 (Analyst, **74**, 387) I proposed what seemed to me at the time to be a useful conventional distinction for rheologists: "by 'replicable' as distinct from 'reproducible' is meant that measurements can be repeated satisfactorily on replicate samples, but not reproduced on samples which have already been tested." Some other rheologists have since used this nomenclature and correctly ascribed it to me.

From recent private correspondence with Dr. H. Umstätter, however, I learn that a somewhat similar type of distinction is already in use. He tells me that, in U.S.A., "repeatability" is officially defined to refer to the reliability of a single operator and apparatus and that "reproducibility" refers to a comparison between different operators and laboratories, these definitions being officially accepted in the A.S.T.M. Standards on Petroleum Products and Lubricants. A comparable distinction also occurs in German, though this has not yet been officially accepted. The British "Standard Methods for Testing Petroleum" proposes the use of the same terms with a different meaning! The matter will presumably be finally settled by the International Standards Organization.

All these definitions differ from mine, both in respect of their terms and in the distinction which they are designed to make. Nevertheless, the use of my proposals may lead to still further confusion and should perhaps be abandoned. What do your readers think? Can other terms be proposed for the distinction I wished to make?

I am most grateful to Dr. Umstätter for his help in this matter.

21st January, 1954.

G. W. SCOTT BLAIR.

The Editor,
The British Society of Rheologists' Bulletin.

Dear Sir,

I feel that Dr. Scott Blair's comment on the divergence of meaning of the terms Repeatability and Reproducibility is open to some misconstruction, and I welcome this opportunity of amplifying his remarks.

So far as I can discover, these terms were first recommended by the I.S.A. and were loosely defined as measures of precision in situations where a single operator repeats a test procedure on a single apparatus (Repeatability) and where the test procedure is carried out in different laboratories (Reproducibility). These terms were first employed by the Institute of Petroleum in their 1942 edition of "Standard Methods for Testing Petroleum," and shortly afterwards by the D-2 Committee of the A.S.T.M. in their corresponding handbook "A.S.T.M. Standards on Petroleum Products and Lubricants."

I.S.A. did not, however, specify what measures of precision should be used for these terms, so that there has until recently been considerable variation in practice even between methods in the same handbook. Thus Reproducibility might be quoted as the standard deviation, or as the average deviation, or as an "acceptable" deviation from the mean or in any one of the other numerous forms which are required by the test operator. Agreement has, however, now been reached between the Institute of Petroleum and the D-2 Committee of A.S.T.M. on a standard form of presentation, and with the publication of the 1953 edition of the latter's handbook, the two terms are identically defined and used.

Although the distinction between the two situations which they represent is an important one, I do not believe that the particular words employed have ever received much favour; they have been retained merely on the score of their long-established usage. I certainly feel that the addition of a third similar and virtually synonymous word would cause confusion particularly as this is proposed to make a distinction of a very different character.

G. W. SEARS,

Chairman, Sub-Committee No. 14—Statistical,
Institute of Petroleum Standardization Committee.

9th February, 1954.

RHEOLOGY ABSTRACTS

2861. **Contact and rubbing of flat surfaces.**

J. F. ARCHARD. *J. Appl. Phys.*, 1953, **24** (8), 981.

The author is mainly concerned with a model of the real area of contact between two mating friction elements. The electrical contact resistance depends upon the model chosen to represent the surfaces, whereas in the region of the validity of Amontons' law the mechanical wear is independent of any assumptions concerning the real area of contact.

R.S.

2862. **Tacky adhesion—a preliminary study.**

W. H. BANKS AND C. C. MILL. *J. Colloid Sci.*, 1953, **8**, 137.

Consideration of the conditions of liquid flow between separating parallel disks suggests that cavitation sets upper limits to the force opposing the separation. On this basis the limiting force should be independent of the liquid and the initial separation of the disks. Some preliminary measurements appear to be in agreement with this, and the bearing on studies of tacky adhesion is discussed.

B.C.R.A.

2863. **Anomalies in the field of microhardness.**

A. BRAUN. *Schweiz. Arch. angew. Wiss. Tech.*, **19**, 67–78 (March, 1953).

A theoretical relation between the elastic and work-hardening properties of a metal in tension and the variation of hardness with applied load in the range 2.5g–50kg, as measured with a pyramidal indenter, is derived and confirmed by observations on several metals. The dependence of microhardness readings on metallic structure is discussed.

SCI. ABSTR.

2864. **Friction and lubrication of surfaces at low temperatures.**

M. N. BUTSCHIN. *Berlin: Akademie-Verlag* (1953) 64 pp. In German, translated from Russian.

Describes experiments in temperature range +150 to –130°C on the static friction of surfaces, lubricated with a number of oils. It is shown that as temperature falls friction first rises with viscosity of the oil, reaching a maximum at a “critical temperature” which is below the melting point of the oil. The subsequent fall of μ is due to hardening of lubricant, and friction becomes dependent on the mechanical properties of the solid lubricant. “Critical temperature” may be used for comparing efficacy of lubricants although this is to some extent dependent on the thickness of the solid lubricant layer. Effective temperature range of oils may be extended downwards by the addition of high polymer compounds. Includes an account of experimental investigations of the friction of ball-races at low temperatures.

FROM SCI. ABSTR. 7225 (1953).

2865. **Basic concepts of extrusion.**

J. F. CARLEY AND R. A. STRUB. *Industr. Engng. Chem.*, 1953, **45**, 970.

Refers primarily to the extrusion of viscous liquids and plastics.

B.C.R.A.

2866. **Simplified flow theory for screw extruders.**

J. F. CARLEY, R. S. MALLOUK AND J. M. MCKELVEY. *Industr. Engng. Chem.*, 1953, **45**, 974.

The flow behaviour of a viscous liquid (plastics) in the channel of an extruder screw is shown to be similar to the flow behaviour of viscous liquids between infinite parallel plates, one of which is stationary and the other moving. Assuming Newtonian behaviour of the liquid, a differential equation was derived that relates the rates of extrusion and the die pressure to the screw and die geometry and to the operating variables. Integrated flow-equations are given for the special case in which the viscosity of the liquid is constant throughout the screw channel (isothermal extrusion). Equations are also given for the case in which the dimensions of the screw channel are functions of their position along the screw.

B.C.R.A.

2867. Application of theory to design of screw extruders.

J. F. CARLEY AND R. A. STRUB. *Industr. Engng Chem.*, 1953, **45**, 978.

The pumping efficiency of a melt extruder (for plastics) is the delivered power, $Q\Delta P$, divided by the total power consumed by the screw. By manipulation of the flow and power equations it is shown that the efficiency of a melt extruder is a function only of the screw and die dimensions and is independent of the screw speed, the throughput, the rise in pressure of the melt, and the viscosity of the melt. Formulae are derived for the design of efficient extruders to pump melts the temperature of which must be closely controlled during extrusion. The effects of 9 design factors on the principal screw dimensions are investigated numerically for a typical example. In extrusion jobs where the melt could absorb only very little of the mechanical heat, large factors of safety have been used to ensure the thermal protection of the melt. The present method offers the hope of substantial savings in both investment and power costs by making it possible to find the smallest extruder of near-optimum efficiency that will safely do the job. B.C.R.A.

2868. Extruder scale-up theory and experiments.

J. F. CARLEY AND J. M. MCKELVEY. *Industr. Engng Chem.*, 1953, **45**, 989.

The design of extruders receiving solid particle or strip feeds is of economic interest to the plastics industry. However, no exptly valid theory of behaviour for the solid in the rear of an extruder has as yet been achieved. Using the theory of melt extruders as a guide, together with exptl. evidence on the behaviour of solids and of "plasticizing" extruders, we have obtained rules for predicting the performance of large extruders from the performance of geometrically similar models. If similar extruders are run adiabatically at equal speeds and one is x times as large as the other, their outputs and power consumptions will be expected to be in the ratio $x^3 : 1$, while their output pressures and temps. will be equal. These rules imply that in many cases the heat of melting can be supplied by the mechanical action of the screw rather than by transfer through the barrel walls. Designs based on this principle should lead to smaller, more economical extruders.

B.C.R.A.

2869. The forced flow of a rotating viscous liquid which is heated from below.

T. V. DAVIES. *Phil. Trans A*, 1953, **246** (907) 81-112.

2870. How to determine the softening point of viscosity.

R. K. DAY. *Ceramic Ind.*, 1953, **60** (3), 64.

A portion of glass fibre prepared for the annealing and strain-pt. measurement may be used. The fibre has a ball fused on its upper end and hangs in the furnace, where it is heated at a constant rate ($10^\circ\text{C}/\text{min.}$) until its rate of stretch is 1mm/min. The temp. at the 1mm/min. rate is the softening-pt. Absolute determinations of the softening-pt. can be made using the strain and annealing-pt. apparatus with very light stretching weights. Standard glasses are now available in the U.S.A. for use in the measurement of the softening-pt.

FROM B.C.R.A. ABSTR. 2551 (1953)

2871. Dielectric properties of flowing Vanadium pentoxide sols.

YU. F. DEĬNEGA, A. V. DUMANSKIĬ AND O. D. KURILENKO. *Koll. Zh.* 1953, **15**, 234.

2872. Dielectric properties of emulsions of the water/oil type when flowing.

YU. F. DEĬNEGA, A. V. DUMANSKIĬ AND O. D. KURILENKO. *Koll. Zh.* 1953, **15**, 361.

2873. Contribution to the study of the dimensions of rigid macromolecules. Comparison of the results of the electron microscope and of the hydrodynamic laws. I. The fundamental theories of the hydrodynamic methods used for the determination of the form and dimensions of rigid particles.

J. B. DONNET. *J. Chim. phys.*, **50**, 291-300 (May, 1953).

An outline of the theories which form the bases of various experimental methods for the measurement of particle size in a suspension. These include the theories of diffusion, both of translation and of rotation, for a system of rigid ellipsoidal particles; of viscosity,

and of sedimentation. The treatment for both mono- and poly-dispersed media is discussed and experimental verifications of the theories are briefly summarized.

SCI. ABSTR.

2874. Contribution to the study of the dimensions of rigid macromolecules. Comparison of the results of the electron microscope and of the hydrodynamic laws. II. Experimental methods used in our study.

J. B. DONNET. *J. Chim. phys.*, **50**, 301-7 (May, 1953).

Discusses measurement by the electron microscope. Schematic diagrams and descriptions of the experimental arrangements are given for the measurement of the coefficients of diffusion of translation by the intensity of light absorption; of rotation by flow birefringence; of viscosity by capillary flow; and of sedimentation by ultracentrifuge. The techniques and accuracies are considered rather fully.

SCI. ABSTR.

2875. Bauschinger effect by torsion of copper wires.

M. J. DRUYVESTEYN AND C. F. ETIENNE. *Appl. Scient. Res.* 1953, **4**, 100.

If a metal is deformed in one direction and afterwards deformed in the opposite direction, the yield value has decreased. This decrease is called the Bauschinger effect. Measurements of this effect for copper wires with the aid of a torsion apparatus showed that it is caused by a mechanism essentially different at temperatures below -40°C from that at temperatures above $+20^{\circ}\text{C}$.

P.G.M.

2876. Thixotropy of clays.

R. FAHN, A. WEISS AND U. HOFMANN. *Ber. dtsh. keram. Ges.*, 1953, **30**, 21.

It has been found that liquid can be volatilized from the frozen thixotropic gels of bentonite, kaolin, and halloysite to obtain frameworks consisting purely of solid particles. With bentonite and kaolin these frameworks isolated from aqueous gels filled the same space as the volume of the thixotropic gels. The bulk density of the bentonite framework was only 0.055g/ml. The frameworks had a measurable crushing-strength; that of bentonite had a considerable elasticity. Such frameworks are probably already present in the thixotropic gel after it has stiffened. This agrees with the fact that the vol. of thixotropic bentonite gels can be reduced by centrifuging for a prolonged time.

B.C.R.A.

2877. Allowance for temperature in the equations of plasticity theory.

N. S. FASTOV. *Dokl. Akad. Nauk SSSR*, **85** (1), 67-70 (1952).

It is shown that, in the tensor formula for plastic deformation, $D\omega = \Psi D_G (D\sigma, D_G = \text{stress and strain deviators respectively})$, Ψ_0 (and hence the shear modulus $\Psi/2$), is a linear function of the temperature, and is not independent of it as usually supposed.

SCI. ABSTR.

2878. The effect of plastic deformation on diffusion.

N. S. FASTOV. *Dokl. Akad. Nauk SSSR*, **85** (2), 309-12 (1952).

The equation for the diffusion of one component in small concentration c into another substance is deduced. It shows that diffusion is determined both by the dependence of the atomic volume on c , and of the yield point on c ; in some cases, e.g. for the diffusion of C into Fe the latter can be neglected, but it cannot in others, e.g. of Au diffusing into Ag, or Ag into monocrystalline Hg.

SCI. ABSTR.

2879. On the theories of the plasticity and workability of clay products and the principal methods for their determination. II.

C. FICAL. *Ceramica, Milano*, **7** (11/12), 79 (1952).

A complete explanation of plasticity is still lacking. The discrepancies between F. H. Norton's colloidal and membrane-tension theories may be reconciled by the one theory becoming complementary to the other. The 2 parameters (the elastic limit and max. extension without breakage) characterizing the plasticity do not give an absolute definition and differ considerably in their interpretation of the character of a clay-water system in the plastic state. No single method or apparatus can give the measurement of plasticity in a single value. The plastic behaviour of clay should therefore always be evaluated on the basis of the sum of a no. of measurements. For measuring plasticity,

the Nadai compression apparatus adopted by Russell and Hanks, and Detaillé's apparatus for testing torsion, seem to give the best results. B.C.R.A.

2880. On solid lubrication.

M. R. FORTRAT. *Helv. phys. Acta*, **26**, (3-4), 191-8 (1953).

Static (μ_s) and dynamic (μ_d) coefficients of friction measured for steel on steel, brass on steel and Al on steel with solid lubricant layers of rosin, wax, graphite and talc, at speeds up to 3cm/sec and pressures from 40 to 150g/cm². With rosin and wax $\mu_s > \mu_d$, with graphite and talc $\mu_s < \mu_d$. SCI. ABSTR.

2881. On the dynamical behaviour of the grain boundary in bubble raft under shear stress.

E. FUKUSHIMA AND A. OKAWA. Note in *J. Phys. Soc. Japan*, **8**, 280-2 (March-April, 1953).

The behaviour of three types of grain boundary is illustrated: (1) High-angle boundary constituted of disordered groups of bubbles. Relative displacement of the adjoining grains occurs without change in position of the grain boundary; during the movement individual bubbles can be seen frequently changing their allegiance from the structure of one grain to that of another. (2) Low-angle boundary of an array of dislocations on parallel slip planes. The dislocations move in unison so as to change the position of the boundary in the manner envisaged by Read and Shockley. (3) Low-angle boundary of dislocations on 2 or 3 sets of non-parallel slip planes. Here the behaviour is similar to (2) until pairs of dislocations on non-parallel slip planes approach to within a limiting distance, when further movement of the boundary is accompanied by changes in its dislocation structure. SCI. ABSTR.

2882. Molecular theory of fluids.

H. S. GREEN. *Amsterdam: North-Holland Publishing Co.* (1952) viii + 264 pp.

Review in *Proc. Phys. Soc. [London] A*, **66**, 668 (July 1, 1953).

2883. Departures of the elastic behaviour of rubbers in simple extension from the kinetic theory.

S. M. GUMBRELL, L. MULLINS AND R. S. RIVLIN. *Trans. Faraday Soc.*, **1953**, **49**, 1495.

2884. Sol-thixotropic behaviour of lubricants.

F. W. HÄUSSLER. *Kolloid Zeits.*, 1952, **126**, 102.

Sol-thixotropy is defined as decrease of viscosity through mechanical working and its recovery after a subsequent period of rest. A reversible transformation of two phases of finite viscosity is involved. Lubricants may show such behaviour. Experiments are described in which the lubricant is sheared by periodic normal movement of a parallel plate arrangement. The forces exerted by the liquid on the plates is measured continuously and is taken as a measure of viscosity. The viscosity of oils decreases rapidly (approx. 45% of initial value) and with some oils increases again. Periods of rest cause, with the liquids investigated, an increase in viscosity, the magnitude of which depends on the duration of periods of mechanical working and rest. K.K.

2885. The growth of fatigue cracks.

A. K. HEAD. *Phil. Mag.*, **44**, 925-38 (Sept., 1953).

2886. Evaluation of the relaxation periods from free torsional vibrations.

E. JENCKEL, H. HERTOGE AND E. KLEIN. *Z. Naturforsch.*, **8a**, 255-66 (April, 1953).

The theory of free vibrations of the Maxwellian bodies enables the measurement of the damping of the polymer substances to be used for evaluating the relaxation periods as function of temperature and for the determination of the shear moduli. These theoretical results have been applied to the measurements of the logarithmic-decrement/temperature dependence of polyurethane, polystyrene, Astralon and Cellon. It is possible to obtain different material constants, the shear moduli, relaxation periods and the heats of activation. No relationship has been found between the freezing temperature and the

maximum damping; the freezing temperature is, however, doubtless the temperature for which the temperature coefficients of the relaxation periods change almost discontinuously. SCI. ABSTR.

2887. Future extrusion studies.

C. H. JEPSON. *Industr. Engng Chem.*, 1953, **45**, 992.

2888. Studies of limiting viscosities of organic liquids by the "blow-off" method.

V. V. KARASEV AND B. V. DERYAGIN. *Koll. Zh.*, 1953, **15**, 365.

In extension of the work described in Abstr. 265 (1945).

G.W.S.B.

2889. Discontinuous flow past a circular cylinder.

M. KAWAGUTI. *J. Phys. Soc. Japan*, **8**, 403-6 (May-June, 1953).

The flow is studied making use of the theory of discontinuous flow and boundary-layer theory. The determination of the separation points is carried out by means of an iterative method. It is found that the separation angle which is measured from a forward stagnation point, is approximately equal to 58° . This angle is very close to the smallest one, 55° , among the angles of separation which can be allowed from the discontinuous flow theory. Thus the flow with separation angles of 55° seems to be the limiting case of viscous flow past a circular cylinder when the Reynolds number increases indefinitely.

SCI. ABSTR.

2890. On the generality of the cubic creep function.

A. J. KENNEDY. *J. Mech. Phys. Solids*, 1953, **1**, 172-181.

The transient creep function $\epsilon = \beta t^m$, where ϵ is the creep strain at a time t after loading, and β and m are constants, is shown to have a wide application to a variety of metallic and non-metallic materials, with m generally having values near to $\frac{1}{3}$. The behaviour of a simple mechanical model, composed essentially of bi-stable units, is shown to approximate to the type of creep observed in real materials. A statistical approach is outlined.

SCI. ABSTR.

2891. Studies in glass-cleaning procedures by static friction measurements.

KOREO KINOSITA. *J. Phys. Soc. of Japan*, 1953, **8** (6), 782.

Five cleaning techniques were employed. With a watch glass loaded with 26g. against a flat glass plate coefficients of friction of between 0.90 and 0.99 were found. R.S.

2892. The method of concentrated shear for the investigation of the elastico-plastic properties and "thickness" (prochnost') of pastes and pseudo-gels.

K. I. KLIMOV AND G. V. VINOGRADOV. *Koll. Zh.*, 1953, **15**, 371.

A special torsion viscometer is described. Mainly concerned with greases. Log deformations *vs* log times for a series of stresses give not very good straight lines.

G.W.S.B.

2893. Increased flow of metals in presence of polar additives in mineral oil.

W. KLINKENBERG, K. LÜCKE AND G. HASING. *Z. Metallkunde*, 1953, **44**, 362.

The Rehbinder effect is confirmed by constant load-flow curves of single crystals of Zn and Cd in mineral oil in the absence and presence of oleic acid. Au behaves similarly, also in the presence of other additives.

L.G.

2894. Stress-strain relations, uniqueness and variational theorems for elastic-plastic materials with a singular yield surface.

W. T. KOITER. *Quart. Appl. Maths.*, 1953, **11**, 350.

The author uses a rather general type of yield criterion which is shown to include the criteria of several other writers as special cases.

R.R.

2895. Dislocations in anisotropic materials.

G. LEIBFRIED. *Z. Physik.*, 1953, **135**, 23.

Slip and screw dislocations are discussed and the elastic constants for crystals of Mg, Zn, Cd, Cu, Ag, Au, Al, Pb and Ge are calculated.

L.G.

2896. **Note on the mean square value of integrals in the statistical theory of turbulence.**

C. C. LIN. *Quart. Appl. Maths.*, 1953, **11**, 367.

2897. **The rheology of printing inks. II. Temperature control in the rotational viscometer.**

G. W. LOWER, W. C. WALKER, A. C. ZETTMAYER. *J. Coll. Sci.*, 1953, **8**, 116.

The thermal effects in a rotational viscometer are studied by means of thermocouples. At energy inputs above 60,000 ergs cm.⁻² sec.⁻¹ the thermal effects become important and can be controlled by lowering of the bath temperature. Materials, which on the basis of previous experiments appeared thixotropic, behave normally if the thermal effects are controlled. L.G.

2898. **Experimental studies of melt extrusion.**

J. M. MCKELVEY. *Industr. Engng Chem.*, 1953, **45**, 982.

2899. **Power requirements of melt extruders.**

R. S. MALLOUK AND J. M. MCKELVEY. *Industr. Engng Chem.*, 1953, **45**, 987.

2900. **Effect of concentration on flow behaviour of glass sphere suspensions.**

S. H. MARON AND S. FOK. *J. Coll. Sci.*, 1953, **8** (5).

Results with glass spheres of size 4 to 12 μ in water-glycerol mixtures can be represented by $\log \eta_r = \frac{ba\phi}{1-a\phi}$ where ϕ is volume fraction, b and a being constants.

A value of 3.15 to 3.35 was found instead of 2.5 for the Einstein coefficient. E.W.J.M.

2901. **Viscosity-temperature v. silicate chain structure.**

C. R. MORGAN AND W. F. OLDS. *Industr. Engng Chem.*, November, 1953.

Viscosity indices and relative viscosity-temperature numbers were determined for several alkyl ortho-silicates and for a representative series of alkyl polysilicates to establish the effect of alkyl structure and siloxane chain structure upon the viscosity-temperature properties.

Three types of alkyl structure were found to have different effects on the rate of change of viscosity with temperature. These may be described as symmetrical primary, unsymmetrical primary, and secondary alkyl radicals. Lengthening or branching of the siloxane chain causes a decrease in the rate of change of viscosity with temperature while cyclization results in an increase. A correlation of refractive index with viscosity was observed within each group of alkyl orthosilicates.

The relative viscosity-temperature number describes the shape of viscosity-temperature curves more satisfactorily than viscosity index and has enabled the classification of alkyl silicates according to the preferred alkyl structure. The best arrangement of silicon atoms in an alkyl polysilicate for least change of viscosity with temperature is also shown by reference to relative viscosity-temperature numbers. A.

2902. **A theory of work-hardening of metals. II. Flow without slip-lines, recovery and creep.**

N. F. MOTT. *Phil. Mag.*, **44**, 742-65 (July, 1953).

2903. **Plastic and elastic properties of high polymers and the kinetic theory of matter.**

F. H. MULLER. *Schweiz Arch. angew. Wiss. Tech.*, **19**, 78-85 (March, 1953).

Qualitative discussion of the rheological behaviour of high polymers in terms of molecular structure and kinetic theory. Mechanical relaxation and creep are interpreted as changes in entropy. SCI. ABSTR.

2904. **An electromagnetic torque-meter for use in viscometry.**

C. A. R. PEARCE. *J. Sci. Instrum.*, 1953, **30**, 232-6.

2905. Clay-slip testing with the vibrating-plate viscometer.

G. W. PHELPS, J. G. WOODWARD, AND S. G. MAGUIRE. *J. Amer. ceram. Soc.*, 1953, **36**, 60.

A series of art-ware and sanitary-ware slips was tested using the vibrating-plate viscometer. Results obtained with this instrument are in the form of "casting-curves" that depict slip consistency as a function of time during casting. Various features of the casting-curves are compared with data obtained by more conventional test procedures. Correlations are found between casting-curve parameters and such factors as initial slip-fluidity, casting-rate, retained water, and quality of finished cast. The physical significance of certain aspects of the casting-curves is discussed. B.C.R.A.

2906. On a method for the solution of hydrodynamic problems in the motion of non-Newtonian fluids.

I. I. ROGACHEV. *Koll. Zh.*, 1953, **15**, 384.

G.W.S.B.

Deals with sharp changes in viscosity with changing stress.

2907. Viscosity of heavy-water vapour.

J. S. ROWLINSON. *Physica*, 1953, **19**, 303.

The ratio of the viscosity of D_2O vapour to that of H_2O vapour was measured by capillary viscometry and found to agree with theory in that it is proportional to the square root of the ratio of molecular weights. L.G.

2908. Method of practical solution of problems of non-permanent filtration flows with a free surface.

G. SCHNEEBELI AND P. HUARD DE LA MARRE. *C.R. Acad. Sci. [Paris]* **236**, 1327-9 (March 30, 1953).

Two practical methods, viz. that of the rheo-electric network and that utilizing conducting paper for solving the filtration equation, given in the form $\bar{V} = -k \text{ grad } \phi$, where $\phi = p/\omega + z$ (the z axis being directed vertically upwards), are very briefly referred to. The result relating to the drainage of a rectangular plot, derived by the method utilizing an electrical network, is given by way of illustration. SCI. ABSTR.

2909. Higher approximation methods for the relaxation spectrum from static and dynamic measurements of visco-elastic materials.

F. SCHWARTZL AND A. J. STAVERMAN. *Appl. Scient. Res.*, 1953, **4**, 127.

Approximation methods for the calculation of relaxation spectra from experimental data from dynamic measurements are given. It appears that better approximations are obtained when higher time-derivates of the moduli are measured. A chart showing quantitative relations between the accuracy of an approximation and the accuracy of various static and dynamic experiments is given. A.

2910. Presentation of rheological results.

G. W. SCOTT BLAIR. *Nature*, 1954, **173**, 156.

A report of the B.S.R. meeting on the 11th December, 1953.

2911. Crystallographic slip in diamond.

M. SEAL AND J. W. MENTER. *Phil. Mag.*, 1953, **44** (12), 981.

The authors suggest that plastic deformation may be produced in the act of polishing diamond. They quote the Knoop indentation hardness of diamond as 5,500 to 6,950 kg./mm² and appreciate that extremely high local pressures must be produced if the lines observed with an electron-microscope can be regarded as slip lines. The angle of incidence of the electrons was 1 to 2° and the viewing angle 6 to 12°. Observation along the polishing grooves revealed a number of roughly parallel lines which could be seen more easily by optical examination of the carbonaceous layer after stripping. This carbonaceous layer is said to have been formed on the surface of the diamond by the action of the electron beam. R.S.

2912. Relaxation phenomena with steel at short duration loading.

G. SEITZ. *Konstruktion*, 1952, 4, 237.

An experimental arrangement is described in which the material can be loaded unidimensionally very rapidly and for a short period of time. A rod of the material is placed in a pressure chamber and is free to move outside in one direction. The pressure is produced by exploding gases or by burning engine fuels. Loads of 60 kg/mm^2 can be reached in 10^{-3} sec. and the period of loading can be varied within wide limits down to 10^{-3} sec. The change of pressure is followed piezo-electrically by a C.R.O. and the strain is registered optically on the same recorder. For a particular steel the elastic limit can exceed the static value by 100%, the incidence of actual creep depends on the time of loading. H.U.

2913. The size and shape of bovine fibrinogen.

S. SHULMAN. *J.A.C.S.*, 1953, 75, 5850.

Using the prolate ellipsoid model, an axial ratio of 18.9 was obtained from viscosity data in terms of the viscosity increment computed from the intrinsic viscosity.

E.W.J.M.

2914. The mechanism of glass polishing.

J. G. SMITH AND J. G. HOOLEY. *Canad. J. Technol.*, 31, 37-41 (Feb.-March, 1953).

In an effort to determine whether glass flows when polished, uranium glasses were fused to nonuranium glasses and polished in a direction from the active to the inactive side. Autoradiographs of alpha tracks were taken before and after to detect any transfer of glass. The method would detect a uniformly flowed layer $4\text{\AA}$ thick if it were over a distance greater than 0.2mm. No evidence for such a flow was found in the case of a typical silicate or phosphate glass polished with a water slurry of ceric oxide or rouge. Radioactive ceric oxide was also used to polish non-active glass. If the contact temperature approached the softening point of the glass and caused flow, then some of the ceric oxide might become incorporated in the surface. The amount was less than $4 \times 10^{-8} \text{ g/cm}^2$.

SCI. ABSTR.

2915. The distribution law of particle size from atomization.

H. A. TROESCH AND P. GRASSMANN. *Z. angew. Math. Phys.*, 4, No. 1, 81-5 (Jan., 1953).

Formulae are derived on classical statistics for the distribution of drops, their surface and volume. Two parameters are contained in the formulae, which fit the facts better than previous ones, the maximum drop diameter which can be calculated and the exchange factor which depends on the type of atomizer.

SCI. ABSTR.

2916. Some questions concerning the theory of the visco-plastic flow of dispersed systems.

N. V. TYABIN. *Koll. Zh.*, 1953, 15, 316.

(Discussion). A reply to criticisms by Volarovich and Gutkin of author's definition of "stay-put-edness" (formosokhranyaemost') of rigid bodies, e.g. metals, as yield-value/ ρg and of his tensorial treatment generally. (An "internal" dispute: no non-Russian work is quoted). (See Abstrs. 1098, 2856).

G.W.S.B.

2917. The "static carrying capacity" of lubricating oils and a "new oil characteristic."

L. UBBELOHDE. *Kolloid Zeits.* 1952, 126, 120.

Previous attempts to determine oiliness dynamically on test-machines were unsatisfactory. The author uses a static method which investigates the behaviour of an oil film between two parallel surfaces which are pressed against each other. Film thickness, as measured by an interference method, decreases with increasing pressure. Under relatively low pressures the oil becomes semi-solid, and it solidifies completely under high pressures (2-3 atms). After solidification the film thickness does not change if the pressure is raised still further. Different oils give different film thicknesses (static carrying capacity) and solidify at different pressures (transformation pressures). It is suggested that these factors can be used for characterising lubricating oils.

K.K.

2918. **Viscosity as a material constant.**

H. UMSTÄTTER. *Kautschuk u. Gummi*, 1952, (4), WT 58.

According to Newton viscosity is defined as the ratio of shear stress to velocity gradient. This postulate is not fulfilled by many colloids and other systems capable of flow, so that the ratio cannot be regarded as a material constant. According to Maxwell viscosity is defined as the product of shear elastic modulus and relaxation time. The problem consists essentially to describe the relaxation process in mathematical form. Solutions are presented for simple deformation, for oscillatory application of shear and for incomplete relaxation, and the material constants are derived. H.U.

2919. **Microviscometry.**

H. UMSTÄTTER. *Makromol. Chem.*, 1953, 10, 30.

In microviscometers which consist of inclined capillaries a surface tension correction must be applied. The correction term can be reduced by increasing the diameter of the ends of the capillary. L.G.

2920. **The plasticity of clays.**

G. VECCHI. *Industr. ital. Laterizi*, 1953, 7, 4.

A review of the better-known theories of plasticity and descriptions of several methods for its determination are given. FROM B.C.R.A. ABSTR. 2535 (1953)

2921. **Oscillation of viscous liquids in tubes.**

S. VENKATARAMAN. *Indian J. of Physics*, 1953, 27 (9), 452.

The viscosity of liquids has been determined from oscillation in U-tubes using the logarithmic decrement, $\frac{1}{2}\nu k^2T$ where T is periodic time, $k=1.2197 \pi/r$, and r the radius of the tube. For stream line flow the radius must be such that the number $r^2/\nu T$ must lie between 5 and 37. E.W.J.M.

2922. **Structure and lubricating action of worked motor oil.**

S. V. VENTSEL'. *Koll. Zh.*, 1953, 15, 331.

Compares absorption spectra (220–420 $m\mu$) for fresh and used oils with their lubricating properties. G.W.S.B.

2923. **Measurements of friction with test-machines and their value for assessing the lubricating properties of oils.**

G. VOGELPOHL. *Erdöl u. Kohle*, 1949, 2, 551.

The author points out that test results cannot be directly used in practical application. The suitability of a lubricant does not depend solely on its properties, and the reduction of friction is a function of operating conditions and the design of the bearing. For developing a suitable test procedure the principles used in model experiments should be applied. The dependence of the generalized coefficient of friction on Sommerfeld's number is shown and agreement between calculated values and those obtained in a large number of experimental results is demonstrated. A useful test-machine should provide results which agree, within narrow limits, with calculated values. K.K.

2924. **The statistical mechanical theory of mechanical processes. VI. A calculation of the coefficient of shear and bulk viscosity of liquids.**

R. W. ZWANZIG, J. G. KIRKWOOD, K. F. STRIPP AND I. OPPENHEIM. *J. Chem. Phys.*, 1953, 21, 2050.

In a previous paper in this series (*J. Chem. Phys.*, 1949, 17, 988) the coefficients of shear and bulk viscosity of liquid argon at its boiling point were calculated using an approximate form of the radial distribution function. Since then more accurate equilibrium radial distribution functions have become available and these are used to calculate coefficients of viscosity. L.G.