

BRITISH RHEOLOGISTS' CLUB



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EDITOR'S LETTER.

The copy for this issue was about to go to the printer when I received an important letter from Prof. E. C. W. A. Geuze, Director of the Soil Mechanics Laboratory, Delft, Netherlands. He writes: "Recently I have been working in close cooperation with Professor Burgers on the establishment of a National Dutch Rheological Society. This plan has now been realized on the 5th of July at Amsterdam. We have started with some 45 members. Professor Burgers will be president; Dr. Saal will be vice-president and I shall take the post of secretary-treasurer. In view of this development I intended to meet you in England and to discuss possibilities of a close cooperation with you in matters of the International Union of Rheology. Members of the newly formed Dutch Society have agreed that it will ask to be considered as an 'adhering organisation' by the International Union. I have been informed by Professor Burgers that Dr. G. W. Scott Blair has not been able to take an active part in matters of international cooperation for some time, due to his illness. This, again I may say, prompted me to give you some details of recent developments over here, which are satisfying in a general way, though I realize that much has yet to be done."

This is welcome news and I feel sure that members will join with me in sending the infant Society (a pretty lusty babe it seems) cordial greetings and wishes for a successful future. An immediate result of the formation of the *Nederlandse Rheologische Vereniging* (*Vereniging* can be translated as either Club or Society!) is that it will make cooperation with the Dutch Rheologists as a body much easier. It is too early yet to say how such cooperation can best be effected, but I hope to keep members posted of developments in the next *Bulletin*.

Change of name: a publishing journal?

The proposal to change our name to "British Society of Rheology" or its equivalent has aroused a certain amount of comment, and some of the correspondence received is reproduced in this issue. It is clear that opinion is divided on this question and we can look forward to a lively discussion in the autumn.

Mr. de Waele raises an important point: should we not have a journal of our own for the publication of original papers? We do try already, of course, to see that original material presented at Club meetings is not lost. Much of the Annual Conference is recorded in book form, and some of the other papers given during the year are eventually published in existing journals. When this is impossible, a summary of the meeting and discussion is usually written for publication in *Nature*, this *Bulletin* or elsewhere. Nevertheless, it is probably true that, as Mr. de Waele says, much useful information at present

gets lost or is not brought up at Club meetings at all. Our own publishing journal would be desirable, but whether or not it can be brought into being depends largely upon finance. Club funds do not allow us at present to run both abstracts and a journal for original papers. It would of course be possible to discontinue the abstracts and devote the space made available to the publication of original papers; but such a drastic change would have to be endorsed by a postal ballot. As far as we know, the general call is for more abstracts rather than less, but if there is a strong feeling that original papers are preferable, we should be glad to know of it.

There is some possibility that when the International Abstracts are under way, the financial saving to the Club will be such that the *Bulletin* can be converted into a publishing organ such as Mr. de Waele has in mind.

A third possibility is a duplicated journal. A modern duplicator can produce work not inferior to the mimeographed publications now so popular abroad and it would save printing costs. On the other hand, the labour of preparing the stencils, operating, collating, etc. (to say nothing of editing the copy) would be heavy and could hardly be undertaken without part-time paid assistance. Cost of such assistance and the necessary materials would wipe out any saving in printing costs.

The problem is thus not an easy one to solve. Perhaps the wisest course at present is to wait until the activities of the International Union become more clearly defined. In any case, the subject can be discussed profitably at the Reading Conference in the autumn.

Abstractors.

I am very glad to be able to report a better response to the appeal for more abstractors published in the last issue. Six members have now come forward with offers of assistance. True, they nearly all wanted to abstract the same journal; but we have now managed to sort things out satisfactorily. The Club is most grateful to these members, the effect of whose work will be apparent in the Abstracts section of this issue. I am, however, still looking for abstractors for the following journals, which continue to be abstracted inadequately or not at all:—

J. Math. Phys.
J. de Physique
Chemie et Industrie
Amer J. Math.
Mathematical Review
Canad. J. Res.

Any offers of assistance with these will be gratefully received.

V. G. W. HARRISON.

CLUB NOTES.

Dr. F. T. Peirce.

We regret to record the death of Dr. F. T. Peirce, a B.R.C. member since 1944 and well known as one of the world's leading textile physicists.

Lectures on Theoretical Rheology.

The Polytechnic, 309 Regent Street, London, W.1., announces that a course of twenty-four lectures on "Theoretical Rheology" will be given by I. Berenblut, M.Sc., A.R.C.S., A.Inst.P., on Wednesday evenings from 7.30 to 9.00, commencing 27th September, 1950.

International Institute for the Conservation of Museum Objects.

Members may be interested to know that an Institute has been formed for coordinating and improving the knowledge, methods and working standards needed to protect and conserve all kinds of precious material. Research, inauguration of training schemes and the publication of a periodical are contemplated. Particulars may be obtained from the Secretary-General, Dr. F. I. G. Rawlins, National Gallery, London, W.C.2.

CORRESPONDENCE

Glasgow, 15 June 1950.

Dear Dr. Mardles,

I quote from Sir Wm. Huggins' "The Royal Society." The Royal Society arose out of a small club, formed about 1645, of "divers worthy persons, inquisitive into natural philosophy, and particularly of what was called the New Philosophy, or Experimental Philosophy."

A few years ago I strongly opposed a *premature* change of name. The time has now come and I approve of "The British Society of Rheologists."

Yours sincerely,

ROBERT H. S. ROBERTSON.

Abbots Langley, 24 June 1950.

Dear Dr. Harrison,

I have just come across an article in the *Proc. Lime Soc. Hertfordsh.*, which would normally wait for abstracting until our September issue.

In view of the current interest to your readers, however, I hope you will agree that this paper deserves immediate publicity, and I have made a rather hurried Abstract which runs something as follows :

Apologia pro Vita Clubae

The countryside was turning green,
When in the Bulletin was seen
A letter from its own Hon. Ed.
Who swore that ere the year was dead
He'd slay the Club.

To call us Club, he said, does mock
The fact that we're a learned Soc.,
And further, ran his arguments,
It's hard for kids and foreign gents
To pay their sub.

Admittedly the oldest hands
Will swell like Osborne Reynolds' sands,
And utter some foul malediction
That's sure to cause internal friction,
Aye, there's the rub.

In spite of this I here would state
(although I joined at recent date)
By all means have a constitution,
But spare the deed of execution,
Let's stay a Club.

H. Lime, Th.E.M.E.

Yours sincerely,

PETER MASON.

(The Hon. Ed. disclaims any intention of slaying the Club, though occasionally he feels like it as Press Date approaches. The arguments advanced in the last number are not his own, but have been expressed by members outside the present Officers and Committee. The ultimate decision whether or not to change our name rests entirely with the membership.)

Tottenham, 7 July 1950.

Dear Dr. Harrison,

I very much enjoyed reading your Editorial in the March issue of the J. Br. Rh. Club, as did most of my staff here. Let us hope that should the Club ever assume the status of a learned society, we shall not be deprived of occasional humorous contributions such as your own in this issue.

I had hoped that one of the strong recommendations for the adoption of "Club" as a designation of our body would be the resulting informality of the proceedings. This hope has indeed been fulfilled in the respect that younger and (sometimes) self-conscious members do not feel the same hesitation in advancing unorthodox observations as if they were in the presence of a "stuffy" Society. My own view as to the attitude of employing firms to the visits of Members to a meeting of the Club is that I think objections are not likely to be raised.

However, this brings me to the main point. I feel sure many members are reluctant to bring to the notice of a meeting or discussion observations which are connected with new, important and often unexplained observations, when they know that in the absence of a publishing organ the matter may be lost, or even unconsciously plagiarised by another member later in a paper published by another Society. In other words, how is it we can afford to publish a Bulletin of Abstracts (which are available to anyone who fulfils his duties as a scientific reader) when we have no record of our activities in a journal of our own?

Yours sincerely,

A. DE WAELE.

RHEOLOGY ABSTRACTS

NOTE.—The initials following the Abstracts are those of the abstracting member except for the following abbreviations for abstracts reproduced from other Journals by permission :—

B.C.R.A.	British Ceramics Research Association.
I.D.I.B.	Industrial Diamond Information Bureau.
NICKEL BULL.	Nickel Bulletin.
P.A.T.R.A.	Printing, Packaging and Allied Trades Research Association.
SCI. ABSTR.	Science Abstracts.
B.S.A.	Building Science Abstracts.

1627. Plastic flow of unmaturred linoleum.

ANON. *Nature* 1950, **165**, 558.

A summarized account of six papers read at a symposium of the Linoleum Research Council. Extrusion techniques, instruments and methods of measurement, and how the analysis of rheological results gives information of the structure and make-up of particular systems are described briefly. The theory of calendaring is discussed.

E.W.J.M. (See Abstr. 1563).

1628. The relationship between molecular weight and polymer viscosity for polyisobutylene.

F. P. BALDWIN. *J. Amer. Chem. Soc.* 1950, **72**, 1833.

Results with unfractionated polyisobutylene (and two 2.5% isoprene —97.5% isobutylene copolymers) covering the molecular range 300,000 to 4,000,000 are in agreement with the relationship

$$\log \eta = A + B \log \bar{M}_w$$

where $\bar{M}_w$ is the weighted average molecular weight and η the melt viscosity.

E.W.J.M.

1629. Further studies of rheological properties of cheese during manufacture and ripening. Part I; Part II. Statistical results.

M. BARON. *Dairy Industry*. 1949, **14**, 146 & 255.

A number of Cheddar cheese were made under instrumentally controlled conditions of firmness of curd at cutting and pitching and of acidity at milling. For each vat of cheese only one of these conditions was varied by a known amount and the effects of such variations on the body of the finished cheese were measured by suitable instruments as well as being assessed by an expert. Attempts were also made to measure the firmness of the curd during the cheddaring but difficulties were encountered because of lack of homogeneity of material. A statistical study is made of the correlations between a large number of physical and chemical tests, giving quantitative expression to the general conclusions. The effects of changes in manufacturing conditions are most clearly seen when the cheese is 14 days old.

G.W.S.B. (abridged).

1630. The relationship between the mechanical properties of Cheshire cheese and graders' judgments.

M. BARON AND R. HARPER. *Dairy Industry*, 1950, **15**, 407.

In many earlier papers, methods have been described for measuring empirically the mechanical properties of cheese and cheese curd. In the present paper, several new instruments are described. The whole battery of tests is applied to the study of the ripening of 200 Cheshire cheese in store during summer 1948. For example, spheres, skewers and needles are pressed into the cheese, rates of depth of penetration being recorded. In one test the energy needed to break a plug of cheese under standard conditions is measured. The firmness, springiness and crumbliness are also judged by experts and others handling the cheese and scores are given for these properties. If each cheese were to be described by all the scores from these tests, physical and "subjective," 14 numbers would be needed for a full description. By application of Multiple Factor Analysis (See Abstr. 1580) the 14 tests are effectively reduced to four significant factors, the most important of which is closely connected with hardness as measured by penetration of a sphere or as assessed by thumbing. Tentative suggestions are made as to the significance of the other three factors. Some rather remarkable correlations were found: e.g., the mechanical test most highly correlated with overall quality as judged by the expert turns out to be the depth of penetration of needles under a standard load.

G.W.S.B. (abridged).

1631. The frictional properties of tungsten carbide.

F. T. BARWELL AND A. A. MILNE. *Proc. 7th Internat. Congress Appl. Mech.* 1948, **4**, 294.

Materials tested were wolfram (tungsten) carbide steel, two bronzes and a white metal, covering extreme range of hardness encountered in engineering practice. Series of lubricants chosen to represent range of oiliness met with in hydrocarbon oils such as oleic acid, B.P. paraffin oil and 2 common lubricating oil formulations. Following general characteristics obtained:—(a) friction of similar materials sliding together is reduced as their hardness increases; (b) friction of hard metal sliding on soft metal diminishes with hardness of softer metal when good boundary lubrication is present but is not generally affected in presence of poor lubricant; (c) friction of soft metal sliding on hard metal is markedly affected by the surface finish of hard metal. Form and nature of damage caused by wolfram carbide sliding over various metals is illustrated.

I.D.I.B.

1632. Strain induced grain boundary migration in high purity aluminium.

P. A. BECK and P. R. SPERRY. *J. Appl. Physics*, 1950, **21**, 150.

A method has been developed for the study of grain boundary migration in high purity aluminium, which allows positive determination of the direction of grain boundary movements. By means of this method it was confirmed that the migration of grain boundaries resulting from surface energy takes place in the direction toward the centres of curvature of the boundaries. On the other hand, strain induced boundary migration, such as occurs in recrystallization, proceeds in a direction away from the centres of curvature of the moving boundaries. It was also found that certain strained grains serve as nuclei for strain-free grains of the same orientation which grow at the expense of neighbouring strained grains. Most of the strain-free grains formed during the annealing of high purity aluminium cold rolled up to about 40% are produced by this mechanism of strain-induced boundary migration, without the formation of new nuclei.

AUTHOR.

1633. The orientation dependence of the rate of grain boundary migration.

P. A. BECK, P. R. SPERRY AND HSUN HU. *J. Appl. Physics*, 1950, **21**, 420.

The results indicate that recrystallization textures developing in the spontaneous recrystallization of deformed single crystals can be accounted for by the orientation dependence of the rate of growth.

AUTHORS (abridged).

1634. Blood Plasma Viscosity.

L. BENSON. *J. Lab. clin. Med.*, 1950, **35**, 667.

Plasma and water in identical capillaries are simultaneously subjected to the same suction. The distance of flow along the capillaries is taken as a measure of the relative viscosity. Sedimentation rates and relative viscosities are compared. For the healthy subject the relative viscosity varies between 1.2 and 1.6, for the unhealthy from 1.6 to 2.2. Examples of the changes in viscosity throughout illness in pulmonary tuberculosis are given.

F.A.G.

1635. Filled Polyethylene Compounds.

R. BOSTWICK AND R. H. CAREY.

Ind. & Eng. Chem., 1950, **42**, 848.

The use of inorganic fillers to increase the stiffness of polyethylene compositions is described. It was found that incorporation of suitable fillers does not substantially affect processing and injection molding characteristics. Silica, carbon, clay, and calcium carbonate fillers were found to be effective in increasing stiffness and, in general, fillers of smaller particle size were most effective. Multifex MM, Clay 33, and Superfloss, for example, in 40% concentration by weight in DYNH polyethylene resin, increased stiffness by approximately 100%. Thus, as regards stiffness these compounds are approximately equivalent to a D-200 resin. Fillers reduced tensile strength, tear strength, and ultimate elongation and raised brittle temperature.

AUTHORS.

1636. Volume changes in the plastic stages of simple compression.

P. W. BRIDGMAN. *J. Appl. Phys.*, 1949, **20**, 1241.

A method has been devised by which the volume changes occurring during plastic flow in simple compression are directly measured in a dilatometer during the flow process. The great superiority of such a direct determination over an indirect determination from the alteration of dimensions is pointed out. Results are obtained for 3 rocks, quartz crystal, and a number of metals, including several grades of steel and Fe. The volume change during plastic flow is not equal to the product of mean hydrostatic stress into the ordinary compressibility in the elastic range, but may vary in a much more complicated way. There are in the first place permanent changes of volume retained after release of stress; these have long been known and may be of either sign. In addition to the permanently retained changes there may be changes of volume during the action of stress which may be notably greater than the permanently retained part and which also may be of either sign. The most striking of these is a component of volume increase under increasing compressive stress which in the upper range of stress near the fracture point may be greater than the normal component of volume decrease, so that the total volume change is retrograde. This component is recoverable and reversible on release of stress. It would appear, therefore, that in at least some cases the irreversible phenomenon of fracture is prepared for in the region immediately below the stress of fracture by the appearance of a reversible change of volume of sign the opposite of that due to the elastic action of the stresses.

AUTHOR.

1637. Dimensions of coiling polymer molecules from viscosity and light scattering.

A. M. BULCHE. *J. Amer. Chem. Soc.* 1949, **71**, 1452.

Molecular dimensions for polystyrene fractions in benzene have been obtained from viscosity and light scattering data. It was found that the root mean square of the distance between the ends of the molecule is approximately equal to the diameter of the molecular sphere needed for the explanation of viscosity.

AUTHOR.

1638. Mechanical Properties of Polyethylene.

R. H. CAREY, E. F. SCHULZ AND G. J. DIENES. *Ind. & Eng. Chem.*, 1950, **42**, 842.

A study of the fundamental and practical mechanical properties of various molecular weight polyethylene resins by means of tensile stress-strain and torsional torque-deflection curves is described. By combining these two techniques, the stiffness properties have been evaluated with good accuracy over an unusually wide range of temperatures. Other mechanical properties, such as stress and strain at the "elastic limit," and energy of strain can also be evaluated quantitatively on the basis of these data. Analysis of the stress-strain curves, appropriate to certain temperature ranges, has been made. In the -30° to $+25^{\circ}\text{C.}$ range, the stress-strain curves are continuously curved and are best described by an exponential-type function which permits the determination of an initial tangent modulus. Below -30°C. a more conventional elastic behaviour is observable and a tangent modulus may be evaluated graphically. Similarly, a modulus is calculable from the initial straight line portion of the torsional torque-deflection curves. It is shown that, over a common temperature range, torsional and tensile techniques yield equivalent moduli. The log modulus-temperature curves for different molecular weight resins show the well-known inverted S-shape with the curves being flat and extended when compared with vinyl or rubber elastomers. These curves coincide at low temperature—i.e., they are independent of molecular weight. As the temperature is increased the curves fan out; the higher molecular weight materials being characterized by higher moduli. An "elastic limit" has been defined as the point on the stress-strain curve where the tangent modulus is 50% of the initial modulus. The corresponding area under the curve is the strain energy. A fundamental relation independent of temperature and molecular weight, consistent with the general exponential nature of the curves, can be stated: The product of the initial modulus and the strain at the elastic limit are proportional to the stress at the elastic limit. On the basis of this principle a unified picture of most of the mechanical properties has been attained.

AUTHORS.

1639. Tentative explanation of hysteresis phenomenon in tension for an elastic polymer which crystallizes.

J. CLOUAIRE. *J. Phys. Radium*, 1949, **10**, 295. *In French.*

In addition to internal friction, two constants are introduced which represent the relative contribution of entropy and internal energy changes to the elasticity of the amorphous material (α) and the proportion of the material (β) which crystallizes. The latter is dependent on the past strain history of the material. These are used to interpret hysteresis obtained by repeated testing at elongations up to 700% extension.

SCI. ABSTR.

1640. Consequent internal stresses in isotropic continuous media in elastic-plastic equilibrium.

P. A. COENEN. *De Ingenieur*, 1950, **62**, W23. *In Dutch.*

A discussion is given of a simple model of elastic-plastic equilibrium, to which Hencky called attention as early as 1924. As this model shows all principal features of the Brandenberger theory of internal stresses, it is used to make this theory more understandable. Starting from the idea of an isotropic continuous medium, it is shown moreover, that in seeking to define consequent internal stresses, the special internal stresses, introduced by Brandenberger, are arrived at in a straightforward way.

AUTHOR (Trans.)

1641. Laminar flow in a curved tube.

R. COMOLET. *C. R. Acad. Sci., Paris*, 1949, **229**, 342. *In French.*

It has been shown (*C. R. Acad. Sci., Paris*, 1948, **226**, 2049) that the critical Reynolds number at which water flowing in a tube becomes turbulent is lowered greatly by a slight curvature of the tube. A quantitative study is here made, using a flexible tube projecting from a reservoir.

SCI. ABSTR.

1642. New machine for testing mechanical properties of materials.

KH. N. DEMENT'EV. *Zavodsk Lab.*, 1949, **15**, 733. (In Russian).

Five-ton machine by author for testing tensile strength of materials. Photograph and detailed diagram. Electric motor drives worm and worm wheel, and this, through a gear reduction, drives another worm gear operating a loading screw (pitch 6 mm.). General transmission ratio 1/4800; thus speed of second worm gear is 0.3 r.p.m.; feed of load screw 1.8 mm./min. Russ. Standard (GOST) 1497-42 specifies rate of feed, independently of test-piece length, to not more than 4 mm./min. up to yield point. New machine thus corresponds to conditions of static load during test. Feed mechanism may also be actuated by hand-wheel through second worm-gear; at 30 r.p.m. of hand-wheel feed, rate is 4.5 mm./min.; to be increased by bevel gears and hand-wheel at movable clamp to 100-150 mm./min. Lower clamp connected to load screw is movable along a guide bar, while upper clamp and weight lever are disposed on knife edges. Weight on pendulum required for 5 tons is about 18 kg.; for 2.5 tons 9 kg., and for 1 ton 1 kg. Sensitivity of graduated dial, at 5 ton rating (20 kg.) is 0.2 mm./kg., for 2.5 ton 0.4 mm./kg. Said to be much better than on existing machines in Russia. A 50 ton universal hydraulic machine designed on author's principles also illustr. Some account of Kommer apparatus and instructions for use; stated to be unsatisfactory in some respects, and are discussed in editorial note.

I.D.I.B.

1643. Study of the boundary layer at supersonic speeds in turbulent flow: Case of flow along a flat plate.

C. FERRARI. *Quart. Appl. Maths.* 1950, **8**, 33.

Flow is assumed to be everywhere turbulent and motion within the boundary layer is investigated in an attempt to clarify assumptions and conjectures relating to the turbulent layer within a supersonic stream. It is found that (within the range of Mach numbers examined) the drag law is formally identical with the drag law for incompressible fluids, and the thickness of the boundary layer obeys a law formally analogous to the law describing the growth of the layer in the incompressible case. Relationships concerned with the velocity and temperature distribution within the layer, and the transfer of heat from the stream to the plate, are also considered.

R.R.

1644. Comments on creep and damping properties of polystyrene.

W. N. FINDLEY. *J. Appl. Physics*, 1950, **21**, 258.

(Letter). Criticism of paper by Sauer, Marin and Hsiao, *J. Appl. Physics*, 1949, **20**, 507.

A.G.W.

1645. Some physical aspects of clay slipping.

J. FLORENTIN. *Silicates Industr.*, 1949, **14**, 10, COBEA Suppl., 209.

The factors which contribute to the slipping of clay deposits in sloping ground are discussed, and importance is laid on the formation of cracks during dry weather, which subsequently allow rain-water to penetrate and produce a hydrostatic pressure. Contributory causes are overloading of the ground and lack of sufficient soil and vegetation. It was found in laboratory and field experiments that the creation of a difference in electric potential between the walls of a well and a ring of electrodes at some distance in the surrounding ground greatly increased the flow of water, thus improving the drainage.

B.C.R.A.

1646. New interpretation of the n -power law in plastic deformation.

H. I. FUSFELD. *J. Appl. Physics*, 1949, **20**, 1052. It is shown that the n -power law describing a true stress-strain curve, normally written as $S = k\delta^n$, can be placed in the form $S = S_0(e\delta/n)^n$ where S_0 is the engineering tensile strength. The application of this new expression to tensile curves is discussed. A plot of S/S_0 as a function of n , for a fixed

value of the logarithmic strain δ , provides a general description of the behaviour of all materials in plastic deformation. Experimental data from the literature are in good agreement with the curves. B.C.R.A.

1647. Study of crack propagation using high speed motion pictures.

H. I. FUSFELD AND J. C. FEDER. *J. Appl. Physics*, 1950, **21**, 261.

Results of experiments using a camera giving 10,000 frames a second are given for flat tensile test specimens for brass and aluminium. It is shown that the velocity of crack propagation is proportional to the square root of the crack length. A.G.W.

1648. Low Temperature Stiffening of Elastomers.

S. D. GEHMAN, P. J. JONES, C. S. WILKINSON, JR. AND D. E. WOODFORD. *Ind. & Eng. Chem.*, 1950, **42**, 475.

The generally observed stiffening of elastomers at low temperatures may be supplemented by the occurrence of crystallization if the elastomers have sufficient regularity of molecular structure and other conditions are favourable. To study these effects, observations of the progressive stiffenings of elastomer compounds at low temperatures were made by measurements of the relative torsional modulus of test strips mounted in racks which were stored at low temperature. The periods of observation extended over 30 to 60 days with temperatures in the range from -59° to -18°C . A correlation was found between density changes due to crystallization as determined dilatometrically and torsional stiffness changes. Factors studied in addition to temperature, included compounding variables such as cure and plasticizer content. Some data were obtained to show the acceleration of crystallization due to compressive stress. Progressive stiffening due to crystallization was observed for vulcanizates of Hevea, Neoprene Type GN, and Butyl rubber, as well as for an 85-15 butadiene-styrene, redox-type, copolymer. The results were interpreted in accordance with concepts of crystal nucleation and growth with necessary modifications due to the molecular structure of elastomers. Although the phenomenon of spontaneous crystallization of elastomers was found to be complicated by many factors, a useful degree of generality appears in some of the results.

AUTHORS.

1649. The analogy between hydraulic jumps in liquids and shock waves in gases.

F. R. GILMORE, M. S. PLESSET AND H. E. CROSSLEY, JR. *J. Appl. Physics*, 1950, **21**, 243.

Liquid flow in open channels can give rise to standing waves and even sudden changes in depth called hydraulic jumps, under suitable conditions. The theory of these is considered and the analogy with shock waves considered. The results of experiments show disagreement between theory and experiment. A.G.W.

1650. Analysis of data on plastics life tests.

W. L. GORE. *Anal. Chem.*, 1950, **22**, 684.

Analytical methods of treating data are outlined, which are generally applicable where individual tests may be divided into two categories (good and bad) and where multiple tests may be run, so that the classifications can be expressed as fractions. Analysis of data on life of plastics is illustrated. AUTHOR.

1651. Frictional loss in visco-elastic substances.

B. GROSS. *J. Appl. Physics*, 1950, **21**, 185.

(Letter). A loss of the type of a "true" frictional loss is considered in addition to that which can be deduced from the dynamic modulus function. A.G.W.

1652. Viscosity of highly compressed fluids.—Correlation with critical constants.

L. GRUNBERG AND A. H. NISSAN.

Ind. & Eng. Chem., 1950, **42**, 885.

The viscosity of highly compressed fluids is correlated with critical constants in the form of a nomograph on which the ratio of the viscosity of the compressed fluid, η_p , to the viscosity of the fluid at moderate (atmospheric) pressure, η_A , is given as a function of the reduced temperature, $T_r = T/T_c$ and of the reduced density, $\rho_r = \rho/\rho_c$. The density was chosen as the second parameter in order to make interpolation in the critical region possible. The nomograph is applicable to highly compressed gases and to liquids near the critical point. The accuracy obtainable is of the order of $\pm 10\%$. A summary of the theoretical considerations leading to the nomograph are given. It is assumed that in a highly compressed fluid transfer of momentum may occur by two mechanisms, one translational, gas-type, and the other vibrational, liquid-type. The following equation is obtained:

$$\log 10 \left[\frac{\eta_p}{\eta_A} - (1 - 0.5 \rho_r)^{2/3} \right] - \frac{1}{4.606 T_r} = 1.855 + \log 10 f(\rho_r)$$

$f(\rho_r)$ is a function independent of the nature of the substance and dependent only on the reduced density.

AUTHORS.

1653. Testing for long period hardness.

A. P. GULYAEV AND E. F. TRUSOVA. *Zavodsk Lab.* 1949, **15**, 842. *In Russian.*

So-called long period Brinell hardness tests at relatively high temp. with steel or sintered carbide indenters. Test-piece remains for considerable time under load, and hardness determined from dia. of impression. In some cases thought that this test serves also for determining heat resistance, strength and creep. In present work long period hardness testing used to investigate effect of alloying elements on properties of solid solutions of aluminium-zinc and aluminium-magnesium. Results tabulated for series of 0.5 to 5% additions of Zn or Mg to Al, with Al content and time periods 3.4% (30 sec.), 2.7% (10 min.), 2.3% (30 min.) and 2.0% (1 hr.). Temp. was 350 deg. C. at which all tests were under monophase (Zn or Mg in Al) conditions of solid solution. Indenter was ball of 10 mm. dia. under 25 kg. load. Highest figures, in kg./sq.mm., were 15.9 and 16.7 for 3% and 5% Mg in 3.4% Al during 30 sec. period, and lowest 2.12 for 5% Zn with 2.0% Al in 1 hr. period. Graphs show Brinell hardness numbers H_B for varying contents of Mg and Zn, with max. 16 (Mg) for same contents as before, and $5\frac{1}{2}$ for Zn. Curves given for 30 sec. and 1 hr. periods and varying contents of Zn and Mg respectively. But Al-Mg alloys are much more easily deformed than those of Al-Zn. Concluded that long period hardness testing is unsuitable for study of heat resistance of alloys.

I.D.I.B.

1654. The general theory of cylindrical and conical tubes under torsion and heavy loads.

J. HADJI-ARGYRIS AND P. C. DUNNE. *J. Roy. Aero Soc.*, 1949, **53**, 558.

The authors consider theory for single and many cell tubes of arbitrary cross section with rigid diaphragms. They discuss eigenfunctions, stresses and deformations, etc., for an open tube, boundary conditions expressed in terms of the undetermined e-coefficients and G-functions, etc.

E.W.J.M.

1655. On the firmness of deformable materials.

R. HARPER. *Amer. J. Psychol.*, 1949, **62**, 553.

The author's earlier interpretations of the data obtained by Scott Blair and Coppen (see Abstrs. 114, 987) have now been extended by the use of Probit Analysis. The advantages of the new method are that the relation between stimulus and response is expressed as a linear regression line, the errors in the parameters derived from the data have been systematically worked out and the value of χ^2 is calculated as a routine, so that heterogeneity in the data is at once detected. Moreover, the method is not restricted to equal

intervals of stimulus difference nor to a symmetrical distribution of values. The relationships are plotted in the form of contour diagrams similar to those used in meteorology. Some modifications in the conclusions reached in the earlier paper are recorded.

G.W.S.B.

1656. Cheese grading. Mechanical properties compared with quality assessed subjectively.

R. HARPER AND M. BARON. *J. Dairy Res.*, 1949, **16**, 363.

A comparison is made between the hardness of over 200 Cheshire cheese as measured by a modified Rockwell sphere indentation hardness tester and the judgments of experts and others who "scored" the cheese by thumbing, etc. in relation to firmness, springiness, crumbliness and overall quality. The cheese were tested at 2 weeks and 8 weeks old. Both subjective assessments and physical measurements made at the earlier age were able to predict with a considerable degree of success the way in which the cheese matured.

G.W.S.B.

1657. Surface effects and the plasticity of Zinc crystals.

S. HARPER AND A. H. COTTRELL. *Proc. Phys. Soc. Lond. B*, 1950, **63** (5), 331.

The effects of various surface treatments on the plastic properties of zinc crystals are examined. Roscoe's observation of the hardening effect of a surface film of oxide is confirmed; electrolytically polished specimens have critical shear stresses of about 33 g/mm² whereas oxidized specimens have values up to 65 g/mm². Similar effects are observed on the rate of creep under constant stress. The Rehbinder effect—softening crystals by immersing them in paraffin and oleic acid—can be produced on oxidized specimens but not on others. Oxidized specimens do not respond instantly to immersion and the time of response is proportional to the viscosity of the liquid. It is suggested that the liquid penetrates the oxide film and reduces its ability to harden the metal; the action of the oxide film itself is not yet clear.

AUTHORS.

1658. Study of methods of increasing the plasticity of lean clays by additions.

J. A. HEDVALL, B. LUNDEN AND F. SANDFORD. *Industr. Ceram.*, 1949, **399**, 150.

Preliminary experiments with various plasticizers indicated that while divalent or trivalent hydroxides increase the plasticity, monovalent hydroxides have a peptizing effect which reduces the plasticity. Thus, NaOH is normally useful whereas Na₂CO₃ is not; Ca(OH)₂ raises the plasticity considerably. Detailed investigations with 4 clays showed that CaO is more effective when slaked after it has been added to the slip, and used in combination with Al₂(SO₄)₃. Large-scale plant tests confirmed this, and gave 0.01% Al₂O₃ and 0.02% CaO as the optimum content for relatively non-plastic body used for insulators.

B.C.R.A.

1659. Research on indentation of taper points and the so-called problem of hardness.

R. L'HERMITE. *Proc. 7th Internat Congress for Appl. Mech.*, 1948, **1**, 426.

Indentations with conical points have been carried out, and a general relationship is derived which gives satisfactory agreement with the tests. Only summary.

I.D.I.B.

1660. Diffusional viscosity of a polycrystalline solid.

C. HERRING. *J. Appl. Physics*, 1950, **21**, 437.

Calculations have been made of the rate of creep in a polycrystalline solid due to self diffusion, following a suggestion of Nabarro. Such behaviour would be expected at high temperatures and at very low stresses. Theory and experiment are compared.

A.G.W.

1661. A general solution for the bending of beams on an elastic foundation of arbitrary continuity.

M. HETÉNYI. *J. Appl. Physics*, 1950, **21**, 55.

The foundations are represented by beams imbedded into an otherwise discontinuous supporting material. There are three independent elastic constants, the resilience of the discontinuous spring layers above and below the beam that is within the foundations, and the flexural rigidity of the beam itself. By adjusting these constants the characteristics of any given elastic supporting medium can be approximately represented. General solutions for the bending of beams with such supports are given for any loading or end conditions, and the results are illustrated by examples. A.G.W.

1662. A theory of the yielding and plastic flow of anisotropic metals.

R. HILL. *Proc. Roy. Soc. A*, 1948, **193**, 281.

A theory is suggested which describes, on a macroscopic scale, the yielding and plastic flow of an anisotropic metal. The type of anisotropy considered is that resulting from preferred orientation. A yield criterion is postulated on general grounds which is similar in form to the Huber-Mises criterion for isotropic metals, but which contains 6 parameters specifying the state of anisotropy. By using von Mises' concept (1928) of a plastic potential, associated relations are then found between the stress and strain-increment tensors. The theory is applied to experiments of Körber and Hoff (1928) on the necking under uniaxial tension of thin strips cut from rolled sheet. It is shown, in full agreement with experimental data, that there are generally 2, equally possible, necking directions whose orientation depends on the angle between the strip axis and the rolling direction. As a second example, pure torsion of a thin-walled cylinder is analysed. With increasing twist anisotropy is developed. In accordance with recent observations by Swift (1947) the theory predicts changes in length of the cylinder. The theory is also applied to determine the earing positions in cups deep-drawn from rolled sheet. B.C.R.A.

1663. Some special problems of indentation and compression in plasticity.

R. HILL. *Proc. 7th Internat. Congress for Appl. Mech.*, 1948, **1**, 365.

Investigation into plastic deformation of material, as by impressions made by ball wedge in plastic body. I.D.I.B.

1664. A simple constant stress apparatus for creep testing.

L. M. T. HOPKIN. *Proc. Phys. Soc., Lond. B.*, 1950, **63** (5), 346.

A simple device is described which can maintain the stress on a creep specimen constant to within 0.8% during uniform extensions up to 100%. The apparatus is suitable for slow rates of strain. Examples are given of creep curves obtained with this device from tests on lead and a lead-tin alloy extending to 1000 and 400 hours respectively; good agreement with the Andrade creep equation is observed in both cases. AUTHOR.

1665. Complex stressing of polyethylene.

I. L. HOPKINS, W. O. BAKER AND J. B. HOWARD. *J. Appl. Physics*, 1950, **21**, 206.

The application of biaxial stressing to polythene which would give elongations of 300-600% under uniaxial tension may lead to brittle fracture with less than 20% elongation at break. Higher molecular weight material may however give several hundred per cent elongation before rupture under biaxial stress. Tentative explanations are given and the apparatus used is described. A.G.W.

1666. Variation of elastic moduli and wave velocity with pressure and temperature in plastics.

D. S. HUGHES, E. B. BLANKENSHIP AND R. L. MIMS. *J. Appl. Physics*, 1950, **21**, 294.

Measurement of the velocity of pulses in rods, since longitudinal waves are at the walls

transformed into rotational waves, gives means of measuring a number of elastic constants for the material, e.g. Poisson's ratio, rigidity, Young's modulus and bulk modulus. Using piezo-electric transducers, the propagation of pulses of known duration in polystyrene and polyethylene are measured at different pressures up to 15,000 lb/in². Over this range Poisson's ratio rises in these materials, but in lucite it is nearly constant.

E.G.R.

1667. Plasticity measurements on ceramic press mixes.

W. HUMMITZSCH. *Berg-u. Hüttenm. Mh. Leoben*, 1949, **94**, 76.

The possibilities of increasing the plasticity of ceramic mixes for the manufacture of welding electrodes are discussed; the Brabender plastograph is recommended for the measurements of plastic properties.

B.C.R.A.

1668. Application of a method of measuring the hardness of microscopically small volumes of matter to the solution of certain problems in physics.

B. S. IOFFE. *J. Tech. Phys., USSR*, 1949, **19**, 1089. *In Russian*.

The most effective method is shown to be by pressure with a pyramidal form of agent. The extent to which load governs the degree of hardness found is not yet clear. Other factors, such as the dimensions, especially the depth, of the indentation, as well as the properties of the superficial metallic layer indented, come into play. In examining the latter it was found that residual stresses, for some still unexplained reason, decreased rather than increased with the size of the deformation. Results are shown graphically for Al, Pb, Cu and β -brass. In all cases hardness diminished with the reduction of indentation depth. After noticing the practical applications of such measurement to glueing, crushing, grinding, polishing, etc., and its use in metallography, the study of residual stress and electrical and X-ray analysis, the article considers the distribution of hardness within a single crystal (cast electrolytic Cu and ferrite crystals are illustrated) showing the influence of both physical and mechanical attributes. Profitable lines of future research on the subject are indicated.

SCI. ABSTR.

1669. Relaxation methods applied to problems of plastic flow.

J. A. JACOBS. *Phil. Mag.*, 1950, **41**, (I) 349, (II) 458.

Relaxation methods are applied, in the case of a material yielding according to the Mises-Hencky criterion, to trace the course of plastic straining in (i) a two-dimensional notched bar under tension, (ii) a sharp-ended bar under specified edge stresses, and (iii) a block compressed between two smooth rigid plates which do not overlap it.

J.G.O.

1670. Flow birefringence of protein complexes.

M. JOLY AND B. RYBAK. *C. R. Acad. Sci., Paris*, 1950, **230**, 1214.

The Maxwell effect has been observed in a rotation viscometer with mixtures such as thymohistone sulphate with Cheval serum in neutral pH aqueous dispersion.

E.W.J.M.

1671. The interpretation of the experimental data on the strength of glass.

G. O. JONES. *J. Soc. Glass Techn.*, 1949, **33** (151), 120.

Main conclusions of experimental work on strength of glass discussed from point of view of A. A. Griffith's flaw theory and of later theories on strength of solids. Following main conclusions derived by most experimenters: (a) condition of surface has profound effect on strength values obtained; (b) strength under prolonged loading is reduced by a factor approaching 3 or 4 for very prolonged loading, below that measured in short-term tests; (c) strength at high temp. (up to about the transformation region) is not appreciably different from that at room temp.; (d) strength of specimens can be increased by a heat

treatment which puts the surface layers in compression; (e) average measured value of strength depends on size or dimensions of test specimens, being increased as these are reduced; (f) thin fibres are very much stronger than "massive" glass specimens, sometimes by a factor as great as 50 or 100, especially immediately after drawing. Various external effects on strength of glass discussed, such as surface condition, prolonged loading, influence of temp., influence of compression and specimen size, etc. 66 ref.

I.D.I.B.

1672. Deviations from Hooke's law and the limits of reversibility.

A. KAMMERER AND A. LAMARE. *C.R. Acad. Sci., Paris*, 1949, **229**, 1121. *In French*.

A theory based on a variable elastic modulus explains the observed dependence of the strength of a beam of plastic material in flexure on the rate of application of stress and on the shape of cross-section.

SCI. ABSTR.

1673. Load induced X-ray line broadening in Nylon filaments.

J. KAUFFMAN AND W. GEORGE. *J. Appl. Phys.* 1950, **21**, 431.

A study of the structural changes in Nylon filaments was made using the changes in dimensions of the X-ray diffraction spots and in the proportion of amorphous to crystalline scattering. The results are discussed in terms of similar effects for metals.

A.G.W.

1674. Internal friction of metals at very high temperatures.

T'ING-SUI KE. *J. Appl. Physics*, 1950, **21**, 414.

Effects other than the internal friction peak (versus temperature), which superpose on the higher temperature side of it, are described. The peak has been attributed to the viscous behaviour of the grain boundaries in metals. The additional internal friction has been shown to be due to the effects of cold-working introduced into the interior of the grains, which remain even after complete recrystallisation.

A.G.W.

1675. Brinell testing balls.

KENAMETAL INC. *Iron Age* 1950, **165** (3), 35.

Precision ground 10 mm. dia. balls now available in Kentanium (basically sintered titanium carbide). Particularly suitable for Brinell testing at elevated temp.

I.D.I.B.

1676. The viscosity and heat conductivity of steam.

F. G. KEYES. *J. Amer. Chem. Soc.*, 1950, **72**, 433.

Correlation of the viscosity values of steam obtained by several workers has been made. The value of the ratio, heat conductivity/product of specific heat and viscosity, is 1.2 and is independent of temperature between 100° and 600°C. The ratio decreases with pressure increase.

E.W.J.M.

1677. Measuring speed of centrifugal high speed impact machines and work expended in fracture of test-piece.

P. G. KOROLEV. *Zavodsk Lab.* 1949, **15**, 723. *In Russian*.

In testing materials an important property is resistance to impact, or resilience, at high speeds. Some research on this recorded from Bezhnik Inst. of Transport Engg. Special impact machine gives linear speed of $v = 125$ m./sec. under load. This does not allow determination of absolute value of resilience, since variation in number of rev. of working disc at which work is expended in fracture of test-piece is less than 0.01%. Another apparatus was designed in which disc driven by belt from a motor, carries impact hammer. Test-piece is fixed on a horizontal slide and at required time is forced against the disc by

a spring. In use disc is given certain speed somewhat above that required, and belt is thrown off. When speed of disc has reached desired level, work piece is released and subjected to blow of hammer. Equations, with graph, are developed for determining work expended in fracture of work-piece in terms of polar moment of inertia of disc. Recording instrument must have accuracy sufficient to record 0.01% energy loss when impact is delivered at 3000 r.p.m. of disc. Ordinary stroboscopes, accelerometers etc. not suitable. Apparatus described and illustr., based on principle of electro-mechanical vibrograph (author's Russ. Pat. Appl. 7445 of Sep. 1st 1948) together with oscillograph. Consists essentially of magnetic circuit with 2 coils, in which electromotive force (e.m.f.) is measured. Graphs of impulses shown, together with diagrams of recording pen, and interpretation discussed. Very high accuracy of record claimed.

I.D.I.B.

1678. The plastic behaviour of solids.

A. McCANCE. *Engineering*, 1949, 168, 570.

A theory is put forward of the changes in physical properties caused by cold working, based on the assumption that atoms can exist in two states: the normal state of the annealed metal with a regular lattice, and the state of cold work with a distorted lattice. The stress S in simple tension is related to the contraction of area a by a formula $S = 2S_0 e^{-\alpha a} \sinh \beta a$. Experimental results for many metals and non-metals are shown to support the theory, and values of the constants S_0 , α and β are deduced for mild steel, Cu, Al and Pb. A theory of creep is based on a theory of diffusion of atoms in materials under constant load.

SCI. ABSTR.

1679. Method of and device for testing foundry sand.

R. L. McILVAINE. (H. S. Simpson) (*U.S. Pat.* 2,485,981, 25/10/49).

A method is described for testing the mouldability. The principle is the measurement of deformation by an increasing load; liquid is added to a hollow cylinder resting on a test-piece made from the sand until the sand collapses. The height of the added liquid serves as a measure of the mouldability of the sand.

B.C.R.A.

1680. The elastic constants of a solid containing spherical holes.

J. K. MACKENZIE. *Proc. Phys. Soc. Lond. B.*, 1950, 63, 1.

The effective bulk and shear moduli are calculated by a self-consistent method due to Fröhlich and Sach. The bulk modulus k is determined by applying a hydrostatic pressure, and the shear modulus μ by applying a simple homogeneous shear stress, to a large sphere. Each hole is surrounded by a spherical shell of real material, and the reaction of the rest of the material is estimated by replacing it by equivalent homogeneous material. For consistency, both the density and the displacement of the outer spherical boundary must be the same whether the hole and its surrounding shell are replaced by equivalent material or not. The effective elastic constants calculated from these conditions are

$$\begin{aligned} 1/k &= 1/k_0\rho + 3(1-\rho)/4\mu_0\rho + O[(1-\rho)^2], \\ (\mu_0 - \mu)/\mu_0 &= 5(1-\rho)(3k_0 + 4\mu_0)/(9k_0 + 8\mu_0) \\ &\quad + O[(1-\rho)^2], \end{aligned}$$

where k_0 and μ_0 refer to the real material and ρ is the density of the actual material relative to that of the real material; in the next approximation k depends on the standard deviation of the volumes of the holes. The dilatation due to a distribution of pressures in the holes is $\bar{p}(1/k - 1/k_0)$, where $\bar{p}$ is the mean obtained when the pressure in each hole has a weight proportional to the volume of the hole. By using the hydrodynamic analogue of the elastic problem, the theory is briefly applied to the theory of sintering, and used to discuss the effective viscosity of a liquid containing small air bubbles.

AUTHOR.

1681. Cellulose ester viscosities by the ball-drop method.

C. J. MALM, L. B. GENUNG AND G. B. LAPHAM. *Anal. Chem.*, 1950, **22**, 656.

The ball-drop method is useful for measuring viscosities of concentrated solutions of cellulose esters. Several ball-drop viscometers are described, which are readily constructed from simple apparatus, are useful over a considerable range of viscosity, and are easily calibrated. Viscosity results expressed in seconds are acceptable for control purposes, but they should be converted to absolute or kinematic units for engineering purposes and for a more thorough understanding of the properties of the solutions. Procedures for the measurement of viscosities and determination of conversion factors are presented. The Faxen equation is particularly useful for the latter purpose. If viscosity data are to have practical significance, it is necessary to use solvents, concentration, and temperature closely duplicating use conditions. Pronounced viscosity effects may be caused by variations in concentration; temperature; solubility; density, viscosity, and purity of solvent; and presence of certain ions. It is not possible to predict viscosities of concentrated solutions accurately from data obtained on dilute solutions.

AUTHORS.

1682. Measurements of mechanical properties of polyisobutylene at audio-frequencies by a twin transducer.

R. S. MARVIN, E. R. FITZGERALD AND J. D. FERRY. *J. Appl. Physics*, 1950, **21**, 197.

Measurements of dynamic viscosity and rigidity in rubberlike solids are usually made by a resonance method, which requires fairly large amplitudes. The present apparatus consists of a transducer producing small oscillatory deformations of a disc of the material, when a driving current is passed through one coil. Another coil in the same transducer has currents induced in it by the mechanical motions of the sample. Results show the increase of rigidity and decrease of viscosity with frequency; also the effects of changing temperature.

E.G.R.

1683. Focussing effects in two-dimensional supersonic flow.

R. E. MEYER. *Phil. Trans. A.*, 1949, **242**, 153.

1684. Study of hardness by the indentation method.

I. L. MIRKIN, S. I. NOVAK. *Zavodsk Lab.*, 1949, **15**, 835. *In Russian.*

References to previous Russian investigations of hardness noted, e.g. on relation between hardness and other properties such as yield point, and on variation of hardness (Brinell) with variation of load. Present work mainly devoted to tests with non-standard loads. Apparatus used must therefore have wider range of load than usual, and tests must include deformation of sphere itself and accurate delineation of profile of impression. Testers used included Diatestor, Brinell, Rockwell and Vickers. In addition to $70\times$ (Diatestor) other microscopes with 50 and $30\times$ were used; accuracy of 0.01 mm. claimed. Micrometers used for determining impression profiles to within 0.0005 mm. Test-pieces were polished, and indenter subjected to preliminary pickling in dilute HNO_3 . Several different steels, and Armco iron, were tested, as well as duralumin, after various forms of heat treatment—mostly hardening or quenching. Hardness R_b ranged from 40 (duralumin) to 65 kg./sq.mm. for special steel Kh12M hardened at 1050°C . Dia. of indenters were from $1/16$ in. to 10 mm.; loads from 125 to 4000 kg. Curves show:

(a) relation of hardness number to load for steels of varying surface hardness and heat treatment; (b) comparison of such relations for different metals of one level of hardness; (c) hardness of steel: KhNM, 52Rc with indenters of varying hardness—ordinary steel, annealed steel, and sintered carbide (Pobedit); (d) the same for another steel: Kh12M, 65 Rc; (e, f) similar relation in respect of depth calculations (dia. of sphere); (g, h) varying Meyer factors n and coefficient a , with hardness H , up to 1000 kg. sq. mm. Generally concluded that among factors causing increased hardness with increasing load must be included elastic deformation of indenter itself, observable even with small loads. When using diamond cone or pyramid to give geometrically similar forms of impression, reduced

hardness is not indicated with varying load within wide limits. Relations between dia. of impression d and load P for all metals tested comply with Meyer's law $P = ad_n$, beginning with loads under which elastic deformation of ball and test-piece is not important. Factor n is also constant beginning with these loads. Technical measurements of hardness with steel ball indenters may be accurately achieved for hardnesses up to 400 kg./sq.mm.* Standard (Brinell) hardness measurements of steel with $P = 30D^2$ (D = dia. of ball) give uniform results, within limits of error, irrespective of ball dia. if of equal hardness; error tends to decrease with increasing dimensions of ball.

I.D.I.B.

1685. Consistency of butter. III. Methods for measuring spreadability, greasiness, rigidity limit under gravity ("Formfestigkeit") and deformability of butter.

W. MOHR AND J. HÄSING. *Milchwissenschaft*, 1949, **4**, 255 and 322.

Continuing earlier work (see Abstrs. 1242, 1243) the authors compare the results of a number of empirical tests for butters made by the Fritz and Alpha continuous processes and in the usual way. There is a fair general correlation between the force required to spread a standard sample of butter and that needed to cut through the sample with a standard wire. The force required to drive a perforated plate through the butter is identified, somewhat surprisingly, with spreadability (Schmierfähigkeit). For soft butters at fairly high temperatures the deformation of a sample under its own weight also forms a useful test.

G.W.S.B.

1686. Thixotropy in high molecular substances.

F. H. MÜLLER. *Kolloid Z.*, 1949, **112**, 1. *In German.*

Observation has shown that certain high-polymer substances, through simple mechanical deformation, pass from a horny, stiff state to a soft rubbery condition, and then slowly revert to their former hardness. This effect was referred to as high-polymer thixotropy, owing to its similarity to the usual phenomena of liquids and gels.

RUBBER RESEARCH ASSOCIATION. *From Sci. ABSTR.*

1687. The instability of yielded mild steel beams of rectangular cross-section.

B. G. NEAL. *Phil. Trans. A*, 1950, **242**, 197.

1688. A method for the numerical calculation of hydrodynamic shocks.

J. VONNEUMANN AND R. D. RICHTMYER. *J. Appl. Physics*, 1950, **21**, 232, Mathematical.

A.G.W.

1689. A resonant bar method for determining the elastic properties of thin lamina.

A. W. NOLLE AND P. J. WESTERVELT. *J. Appl. Physics*, 1950, **21**, 304.

A resonant bar method for obtaining the dynamic elastic properties of a thin cement layer is discussed. Formulae are deduced for the calculation of Young's modulus from the measured resonant frequency and band width of two similar steel bars, cemented end-to-end. The accuracy of the method is discussed.

AUTHORS.

1690. Some measurements of hardness of metals using a micro-hardness tester.

M. ODAKA, Y. KURIYAMA, T. KITANI, E. EUMURA. *Nippon Kinzoku Gakkai-Si* 1949, **13**, 29. *In Japanese.*

Previous report concerned a micro-hardness tester developed by the authors; now they describe some experiments with the tester in testing metals. Tester consists of a

table carrying the specimen and a loaded beam, end of which carries the (Vickers) diamond pyramid. Apparatus is mounted under microscope with vertical illuminator and beam is swung out of field of microscope when indentation is measured. Claimed that apparatus allows testing hardness of individual structures in a metal with an accuracy within 1 to 2%. Test results on iron with loads from 7 to 29 g. are given, and compared with the standard diamond pyramid hardness with loads from 1 kg. to 20 kg. I.D.I.B.

1691. Elastic properties of ox synovial fluid.

A. G. OGSTON, J. E. STANIER, B. A. TOMS AND D. J. STRAWBRIDGE. *Nature*, 1950, **165**, 571.

Synovial fluid is non-Newtonian in flow behaviour and when subjected to periodic stresses in a coaxial cylinder elasto-viscometer exhibits shear elasticity. It is possible that the shear elasticity is of significance with regard to the function of the synovial fluid in joints. Thus, the fluid will yield less under stress rapidly applied than if it were a merely viscous liquid and this might serve to protect the synovial membranes when a sudden stress is applied to the joint. E.W.J.M.

1692. Mechanism of the plasticity of homogeneous metal alloys at high temperatures.

K. A. OSIPOV. *Bull. Acad. Sci. U.R.S.S.*, 1949, **9**, 1372.

One of the most important features of the plasticity of homogeneous metallic solid solutions at high temperatures is the process of increased heterogeneous distribution of the components, i.e. the formation of later concentrations which can reach different degrees of importance up to the formation of a new phase. Those solid solutions, the limiting solubility of which changes only slightly with increased temperature, possess the highest resistance to plastic flow. The resistance of a homogeneous solid solution to plastic deformation is in direct proportion to the degree of separation of another phase from it (if the latter phase can exist with it according to the equilibrium diagram). If such a phase is a chemical compound instead of another solid solution, the separation is more intensive. B.C.R.A.

1693. Correlating viscosities—caustic soda solutions.

D. F. OTHMER AND S. J. SILVIS. *Ind. & Eng. Chem.*, 1950, **42**, 527.

Viscosities of solutions of solids in liquids or of mixtures of liquids have been correlated on a logarithmic plot against vapour pressures or viscosities of a reference substance at the same temperature. In the important case of aqueous solutions of caustic soda, the plot of viscosity against the viscosity of water eliminates the break in the function otherwise experienced at 40°C. A nomograph is presented. AUTHORS.

1694. About some physical-chemical investigations of printing inks.

A. G. PARTS. *Istanbul Univ. Fen. Fak. Mec. Ser. A*, 1950, **15** (1), 65.

The "misting" properties of some news inks prepared on a tall-oil basis are investigated in a two-roller apparatus, the construction of which is described in detail. A weighed cellophane sheet is placed below the rollers and in each experiment the inked rollers are kept in motion for 3, 3 and 4 minutes with 2-minute intervals during which amount of ink thrown off is estimated by weighing the cellophane sheet. Circumferential streaks develop on the rollers and an oscillatory movement in the direction of the axis of rotation must be added in order to eliminate them. The quantity of ink collected on the cellophane sheet depends largely on the amount applied to the rollers in the first place. There is no direct connexion between the amount collected and the viscosity of the ink, but the properties of the vehicle certainly influence the misting tendencies. "Non-misting" inks, diluted with xylene, show a clear Brownian movement under the microscope, the carbon particles being separate with little tendency to clump together: the Brownian movement can be observed for a long time. "Misting" inks, on the other hand,

show large irregular aggregates of carbon particles. The same can be observed with thin translucent layers of undiluted inks. The two types of ink can be differentiated in the roller apparatus, since the amount of ink collected on the cellophane falls off more rapidly with time with "non-misting" inks than with "misting" inks. The inks with Brownian movement show as a rule small yield values compared with the other type of inks. The application of a shearing force to the "misting" type of ink diminishes the dielectric constant. A reproducible limiting value of dielectric constant can be reached with intensive shearing, and the dielectric constant then increases steadily with time after removal of the shearing force: there is no indication that an upper limit is reached even after 17 days at rest. The "non-misting" inks with Brownian movement show a very small change in dielectric constant after cessation of the applied shearing force. This effect is probably due to the development or non-development of a structure within the ink, but the time-dependence of the dielectric constant of an ink and its yield value do not run parallel. A preliminary report on these observations has been published in *Nature*, 1945, 155, 236.

V.G.W.H.

1695. Micro-hardness testing.

E. C. W. PERRYMAN. *Metal Ind.* 1950, 76 (2), 23.

Traces micro-hardness testing from Knoop's indenter, elongated 4-sided pyramid diamond with obtuse included angles. Describes apparatus of H. Lloyd and R. Jeffrey using square based diamond pyramid indenter (Vickers pyramid) to be placed on standard microscope. Minimum total load applied is 16.85 g.; breaking of electrical circuit indicates that load is applied to diamond. Tests carried out to determine extent to which hardness is affected by orientation in case of Tadanac lead and high purity annealed copper. Micro-hardness tester measures hardness of very thin metal foil, impossible by ordinary methods because of penetration depth of indenter: also measures hardness of thin electro-deposited coating and of separate phases in structure, and determines age hardening.

I.D.I.B.

1696. Coefficients of friction.

E. C. PIKE. *J. Roy. Aero Soc.*, 1949, 53, 1085.

The author presents information on coefficients of friction (rolling and sliding) between rubber tyres and road or runway surfaces. The results show the variation of sliding friction with various parameters at speeds up to 40 m.p.h.

E.W.J.M.

1697. An optical method for measuring the stress in glass bulbs.

W. T. READ. *J. Appl. Physics*, 1950, 21, 250.

The theory and technique of measurement for applying photoelasticity to this problem are discussed.

A.G.W.

1698. Large elastic deformations of isotropic materials. VI. Further results in the theory of torsion, shear, and flexure.

R. S. RIVLIN. *Phil. Trans. A*, 1949, 242, 173.

The forces necessary to produce certain simple types of deformation in a tube of incompressible highly elastic material are discussed generally. The case of a stored-energy function $W = C_1(I_1 - 3) + C_2(I_2 - 3)$ is considered in detail.

J.G.O.

1699. The influence of the nature of the dispersion medium on the rheological properties of a deposit of quartz powder.

V. ROMANOVSKY. *C.R. Acad. Sci., Paris*, 1949, 229, 871. *In French.*

Deposits from quartz suspensions show yield values which decrease with increasing concentration of NaCl in the dispersion medium. Suggested that it is an electrostatic effect of the NaCl on the water absorption of the quartz.

SCI. ABSTR.

1700. Transparent "metals" and new possibilities of optical strain analysis.

G. ROSENBERG. *Uspek Fizichesk Nauk* 1949, **38**, 590. *In Russian.*

Optical method is a most valuable way of studying strain or stress in machine components. Since metal is opaque this must be done with models of glass or plastic material, and scope of study therefore limited to cases where metal can be regarded as isotropic and homogeneous; ignoring cold-hardening, fatigue, creep, residual stress, recrystallisation, and all factors in hot or cold metal working. Next step to select suitable transparent material of poly-crystalline structure and properties similar to those of metals. Leningrad Physico-Techn. Inst. of Acad. Sci. has solved this problem (*Zhurn Techn Fiz* 1949, **19**, 205) through the work of A. V. Stepanov. In 1933 he found that halide salts of silver and thallium and mixtures or alloys based thereon fulfilled required conditions, including transparency and micro-structure. These could therefore justifiably be termed "transparent metals." Silver chloride crystallises in cubic system, and at room temp. has properties similar to those of copper, but with about one-tenth the strength, and outwardly resembles lead. Illustr. shows rod of AgCl 3 mm. thick, tied in knot, showing that like metals it has tendency to strengthen under plastic deformation. In compression Young's modulus of test-piece is about 4,500 kg./sq.mm. In absence of stress crystals are optically isotropic; under external load there is double refraction which disappears when load removed. Residual internal stress is accompanied also by double refraction (residual) and both may be eliminated by suitable heat treatment. Since AgCl is decomposed by light, test-pieces usually have yellowish or violet colour with an oily lustre. By filtering out active part of spectrum, colouring of test-piece avoided. Concluded that AgCl and other "transparent metals" are uniquely valuable in optical study of stress in metals by means of models, and open up new possibilities in metal research, including hardness, recrystallisation, intergranular reactions, etc. Some results of such study in original, more particularly in regard to residual stress resulting from pressing. Further study of possibilities of "transparent metals" necessary.

I.D.I.B.

1701. Theory of the pendulum hardness tester (sclerometer).

V. N. ROZHANSKII. *Zhurn Tekhn Fiziki* 1949, **19** (9), 1056. *In Russian.*

Use of pendulum for hardness tests proposed by D. I. Mendeléeff, 1898, and by E. G. Herbert Ltd., 1923 (*Eng.* 1923, **85**, 390), based on damping out of pendulum oscillations, using hard ball on surface of test-piece. P. A. Rebinder's work also noted (*Zeits f Phys* 1931, **72**, 191), and his formula for hardness H reproduced in terms of time and fading amplitudes. Hardness usually independent of size of amplitude. Time is main factor, and easily show that H has time dimension and equals subtangent of curve relating amplitude and time. Roller used to support pendulum on surface of test-piece, as this has less slipping effect; and radius of support curvature is very small. High pressure developed at surfaces of contact of support and base may involve local crushing or compressing of latter. Equations developed for moments of force acting on pendulum in respect of any momentary axis, for hardness H independently of amplitude and time. Pendulum hardness and Rebinder's absolute hardness are combined in an equation. Development of microcracks and depth deformation in test piece discussed. Expressions given for function representing relative number of flexible "bonds" or "degrees of completeness" of hard (solid) body, and for functions relating deformation and movement of (support) roller through sufficiently thin stratum. Equations also relating to elasticity limits of test piece; and to friction moment of roller. Generally concluded that Rebinder's formula for small penetrations of pendulum ball (roller) into test piece surface, under conditions of small amplitudes when given equation is applicable, has real physical basis, and may be expressed by mechanical parameters of hard body (test-piece). Thus it may be applied to distinguish surface deformations.

I.D.I.B.

1702. **The viscosity of rare gases.**

A. M. SAULGEOT. *C.R. Acad. Sci., Paris*, 1950, **230**, 922.

Values, determined by the oscillating disc method are given for neon, krypton and xenon between -180° and 20° C in terms of the equation $\eta/\eta_0 = (T/T_0)^n$ where η_0 is the viscosity at temperature T_0 and n having the value shown in the table

Gas	Atomic mass	n
He	4.00	0.65
Ne	20.2	0.77
A	39.9	0.82
Kr	82.9	0.90
Xe	130.2	0.92

The theoretical significance of the relation with atomic mass is discussed.

E.W.J.M.

1703. **An investigation of the flow processes in high polymers.**

W. SCHEELE. *Z. Naturforsch.*, 1949, **4a**, 433. *In German*.

The rate of flow is expressed as a power function of the shearing stress and from this the work of deformation is defined. Polyvinyl acetate gives linear curves plotting $\log$ (stress) $v.$ $\log$ (rate of flow). The slope of these curves is approx. independent of temp., but their position is strongly temp. dependent. $\log$ (work of deformation) is linearly related to the reciprocal of the temp. and the slope of this curve depends on the degree of polymerization.

SCI. ABSTR.

1704. **Mechanism of friction in the "extreme-pressure" region.**

R. SCHNURMANN. *Proc. 7th Internat. Congress Appl. Mech.*, 1948, **4**, 248.

Experiments made with a 4-ball apparatus to show that with a lubricant in region of validity of Amontons' law, major portion of abrasion takes place during starting torque. Main portion of mechanical energy dissipated by friction is converted into heat both by deformation of friction elements and by shearing of boundary layer. An energy balance based on these considerations would appear to allow for an appreciable proportion of the mechanical energy being available for the separation of electrostatic charges.

I.D.I.B.

1705. **A bending method for measurement of the tensile strength and Young's modulus of glass fibres.**

D. SINCLAIR. *J. Appl. Physics*, 1950, **21**, 380.

The method consists of twisting a loop in the fibre and pulling the ends until the loop breaks. The value of the modulus is almost unchanged as compared to the usual straight fibre method but the tensile strength is two or three times higher. These results are explained on the basis of the distribution of flaws.

A.G.W.

1706. **A note on collapsing cylindrical shells.**

T. E. STERNE. *J. Appl. Physics*, 1950, **21**, 73.

Expressions are obtained for the instantaneous dependence of pressure upon radius within a collapsing cylindrical shell of incompressible liquid when subjected to (a) neither external nor internal pressure or to (b) an external pressure but no internal pressure. Dynamical considerations suggest that very high pressures and radial velocities should be reached.

AUTHOR.

1707. **Resistance-wire strain gauges.**

J. G. STRONG. *J. Roy. Aero. Soc.*, 1950, **54**, 19.

A general description of methods and equipment.

E.W.J.M.

1708. The activities of the cement and concrete institute for the period July 1, 1946 to June 30, 1947.

SVENSKA FORSKNINGSinSTITUTET FÖR CEMENT OCH BETONG; *Handlingar No. 11, Stockholm*, 1948.

Director's review of the research programme with emphasis on the plasticity of concrete. The many lines of approach to the central problem include: binding of water by clays, measurements of boundary potentials, fluidity of fresh concrete, and photographic study of the sinking of a concrete surface during vibration, a study of stress distribution in a concrete specimen subject to a bending moment.

P.M.

1709. A note on the kinematics of plane viscous motion.

J. L. SYNGE. *Quart. Appl. Maths.*, 1950, **8**, 107.

Hamel's theorem on 2-dimensional motion of an incompressible fluid is generalised for a compressible fluid as follows: If the vorticity ω and the expansion θ are defined within a space inside a connected boundary, a necessary and sufficient condition that the velocity components shall vanish on the boundary is that $\int (2\omega U - \theta V) dx dy$ shall be zero, where U is an arbitrary harmonic function and V its conjugate harmonic function.

R.R.

1710. A rational basis for the viscosity index system.

J. TADAYON, E. W. HARDEMAN AND A. H. NISSAN. *J. Inst. Petrol.*, 1949, **35**, 28.

Steps are given which led to the construction of a nomograph presented in the form of a chart. The determination of the rational viscosity index n for an oil is carried out by connecting any two viscosities of the oil to their respective temperatures. The position of the point of intersection in the family of n loci determines the value of n .

E.W.J.M.

1711. Transmission of elastic waves through a stratified solid medium.

W. T. THOMSON. *J. Appl. Physics*, 1950, **21**, 89.

Mathematical solution for oblique incidence.

A.G.W.

1712. The structure of paper.

D. TOLLENAAR AND G. BLOKHUIS, *Appl. Sci. Res.*, 1950, **A2**, 125.

A structural description of paper, assuming a size distribution of pore radii, can give a better explanation of the striking-away phenomenon and of capillary flow than a simpler description, given by a mean pore radius and a pore density only.

P.G.M.

1713. A generalisation of Alfrey's theorem for visco-elastic media.

H. S. TSIEH. *Quart. Appl. Maths.*, 1950, **8**, 104.

It is shown that the stress distribution in an isotropic visco-elastic material, which is compressible and subject to body forces, is identical with that in a purely elastic material under the same instantaneous surface and body forces. (It is assumed that the relations between the components of stress and strain and their time derivatives are linear, corresponding to problems of small strain.)

R.R.

1714. Principles of the theory of strength and plasticity.

G. V. UZHIK. *Bull. Acad. Sci. U.R.S.S.*, 1949, **10**, 1433.

The modern theory of strength and plasticity of metals should be based on the conception of the dual nature of the maximum stresses, *i.e.* of the normal, and of the tangential stresses $T_{\max}$, acting in each point of the deformed body, and also of the dual character of the resistance of the material, *i.e.* the resistance to breaking by normal stresses,

and the resistance to shearing by tangential stresses. The resistance of materials to destruction characterizes their ability to resist elastic deformation. The investigation of this new strength characteristic shows that it is a constant, independent of the state of stress. The conception of the dual nature of the stresses and the dual character of the resistance of the material, as well as the acceptance of the resistance to breaking as one of the main characteristics of strength, make it possible to determine the conditions of transition of material to the basic limiting states, *i.e.* breaking away and shearing. This also refutes the previous practice of contrasting the criteria of strength based on the maximum normal stresses (elongation) and maximum tangential stresses; the new theory establishes the unity of the conditions of strength and plasticity. This has made it possible to establish (1) remarkable features of anisotropic compression; (2) a new criterion of brittleness and plasticity; (3) a theory on the load-bearing ability of metals; (4) the reason for the considerable rise of the limiting strength of specimens turned from plastic metals; (5) the answers to some questions of the strength under variable loads (fatigue), etc.

B.C.R.A.

1715. Tangential viscous forces at high velocity gradients.

M. G. VIGUIER. *Experientia*, 1949, 5 (10), 397. *In French.*

The viscous stress is derived from classical kinetic theory retaining third-order terms in the velocity gradient; the result is applied to the case of flow over a flat plate in an incompressible fluid. The theoretical curve of the viscous drag against R has a minimum.

SCI. ABSTR.

1716. Yield points in Zinc crystals.

H. L. WAIN AND A. H. COTTRELL. *Proc. Phys. Soc. Lond., B*, 1950, 63 (5), 339.

It is shown that sharp yield points can be produced in crystals of zinc containing nitrogen. The gas is introduced in a preliminary melting operation, either by bubbling it through the metal or by allowing it to be absorbed from the atmosphere, using a flux to keep the surface clean. Strain ageing treatments are needed to develop the yield point clearly, but once it is developed it returns at the same level after each successive treatment at the same temperature. Ageing experiments at room temperature show that overstrained zinc crystals soften by recovery before the yield point returns; zinc differs from iron in this respect. General conditions for producing yield points in metals of common crystals structures are briefly discussed.

AUTHORS.

1717. A contribution to the hydrodynamics of lubrication.

G. H. WANNIER. *Quart. Appl. Maths.*, 1950, 8, 1.

The relation between Reynolds' approximate equations (applicable to thin lubricating films) and the more accurate equations of Stokes is explained. The rigorous solution of Stokes' equations for a cylindrical bearing is considered, new formulae being obtained for the load carried and the coefficient of friction, and a number of limiting cases are considered in detail including that case in which Reynolds' approximation is applicable. The problem of a spherical bearing is found to be intractable in general, but it is solved in the case of the Reynolds limit. The results are, at present, of limited usefulness because of the negative pressure difficulty.

R.R.

1718. Molecular weights of the polyphosphates from viscosity data.

J. R. VAN WAZER. *J. Amer. Chem. Soc.*, 1950, 72, 906.

Viscosities were measured of dilute solutions of sodium phosphate glasses in water containing 10% tetramethyl ammonium bromide and it was found that the intrinsic viscosity was linearly related to the average number of phosphorus atoms per polyphosphate chain.

E.W.J.M.

1719. Depolymerization by ultrasonic irradiation : the role of cavitation.

A. WEISSLER. *J. Appl. Physics*, 1950, **21**, 171.

Experiments with 1% polystyrene solutions show that when adequate precautions are taken (by boiling under vacuum) to prevent cavitation, no change in molecular weight occurs when the solution is exposed to ultrasonic radiation. Similar results were obtained using hydroxyethyl cellulose. The production of degradation in the presence of helium alone shows that the effect is not due to oxidation.

A.G.W.

1720. The rheology of paper coatings.

W. R. WILLETS. *TAPPI*, 1950, **33** (4), 201.

Curves obtained with a Brookfield Synchroelectric viscometer are reproduced showing apparent viscosity against speed of rotation for a number of coating mixes. The effect of total solids content and of storage are discussed.

V.G.W.H.

1721. The mechanism of deformation in metals, with special reference to creep.

W. A. WOOD AND W. A. RACHINGER. *J. Inst. Met.*, 1949, **17**, 237.

A study has been made of the changes in crystalline structure produced at various temps. when a metal is subjected to the slow rate of strain typical of the creep process and also to the relatively rapid rate associated with ordinary mechanical testing. Measurements were made at the same time of the strength developed in the metal under the various conditions of deformation. The object was to investigate the underlying mechanisms of deformation and in particular the relation of deformation by creep to the more familiar deformation by slip. The results show that the grains develop a substructure of a size determined by the temp. and rate of strain. The mechanism of deformation changes from slip to creep as the elements of the substructure exceed a certain size. For a given rate of strain the size of the elements in the substructure is larger the higher the temp.; for a given temp. the elements are smaller the more rapid the rate of strain. The strength and strain-hardening capacity of a metal decrease as the substructure becomes coarser, and on this observation an explanation of creep is based. AUTHORS.

1722. Experimental study of the Maxwell effect with solutions of chain macromolecules in terms of solvent viscosity.

R. CERF. *C. R. Acad. Sci., Paris*, 1950, **230**, 81.

The viscosity measurements at temperatures between 7° and 50°C. with aqueous dispersions of tobacco mosaic virus are in agreement with the classical theory of orientation. Viscosity results between 0° and 60°C. with polystyrene in cyclohexanone contradict the theory of Kuhn and Kuhn but are in agreement, as far as the Maxwell effect is concerned, with the view that the chains behave as elastic spheres with constant internal viscosity.

E.W.J.M.

1723. Flow of plastic systems.

F. CHARRON. *C.R. Acad. Sci., Paris*, 1950, **230**, 614.

The author has developed an equation involving frictional forces and the viscosity coefficient for the movement, at constant rate, of plastic materials, such as a grease, between two parallel surfaces under various pressures.

E.W.J.M.

1724. The viscosity of aero engine oils at low temperatures.

S. G. DANIEL. *J. Inst. Petrol.*, 1949, **35**, 516.

A description is given of the method of determining the viscosity of oils using a suspended level type I.P. viscometer and a plastometer to -60°C. Thixotropy and non-Newtonian flow were observed at the lower temperatures.

E.W.J.M.

BOOK REVIEWS

INDENTATION HARDNESS TESTING.

VINCENT E. LYSAGHT. Rheinhold Publishing Corporation, New York. \$5.50; and Chapman and Hall, Limited, London. 44/-.

Whatever may be the complete interpretation, in terms of fundamental physical properties, of the resistance of a substance to plastic deformation, the experimental fact remains that modern techniques of indentation hardness testing afford an index of quality which is remarkably consistent and instructive. Combined with the rapidity and simplicity of the test, which is practically non-destructive and can be applied with a minimum of preparation to an actual component (as distinct from a separate specimen assumed to be representative) these advantages offer an attractive means of production quality control. During and since the war, consequently, experience of indentation hardness testing has markedly expanded, and the corresponding scientific interest, both in its practice as an industrial routine and in the endeavour to understand its metallurgical implications, has led to advances of knowledge in a number of directions.

Nevertheless, so thorough and comprehensive are some of the earlier books, to have a worthy successor to them calls for truly authoritative theoretical and practical knowledge of hardness measurement. Mr. Lysaght modestly disclaims such qualifications, but his 20 years of experience in designing and using hardness-testing apparatus, his obviously keen interest in every aspect of the subject, and the respect which his opinions command in the United States, are evidence of his ability to present a competent statement of important trends in hardness investigation. This he does, in concise and readable style, after a sufficient historical introduction to the principles underlying hardness assessment and a critical survey of indentation testing machines, among which the dynamic Scleroscope and several types of portable instruments are included.

Among recent developments in hardness testing, the elongated rhomboidal impression of the Knoop indenter is of unusual interest as being not yet widely known or used in this country for testing thin sheet material, hard cases and electrodeposited coatings. Mr. Lysaght deals expertly with these applications and writes instructively about the special problems raised by sheet metal, cylindrical surfaces, hot hardness, micro hardness, and the indentation testing of non-metallic materials, paying detailed attention to the techniques of measurement required in different applications and to the relationship and significance of the index values obtained from different instruments. The interest of his book to research workers is thus enhanced without detriment to its value to industrial metallurgists and mechanical engineers, and his well-illustrated and fully-documented text can be recommended as a lasting contribution to a science of growing importance.

Engineering.

ELEMENTS DE CALCUL TENSORIEL.

A. LICHNEROWICZ. Collection Armand Colin, No. 259. Librairie Armand Colin, Paris. 180 fr.

The idea of a tensor was first introduced by W. Voigt in connection with his researches on the physics of crystals. Its basic character was, however, not fully appreciated by physicists until the investigations of the properties of tensors by mathematicians, culminating in the celebrated memoir of Ricci and Levi-Civita (1900), exemplified the application of tensors in geometry and classical mathematical physics and provided the natural vehicle for the formulation of Einstein's theory of relativity. Tensors may be regarded as a generalisation and extension of vectors to space of more than three dimensions, so that Professor Lichnerowicz's book provides a sequel to Bricard's *Vector Calculus*, which appeared earlier in the same collection.

Physical entities, having an independent existence, must be capable of expression in a form that is independent of any arbitrary choice of a co-ordinate system of reference.

The tensor calculus, in virtue of a notation of great compactness and flexibility, not only enables general physical equations to be expressed with remarkable conciseness, but serves as an invaluable guide for the selection of physical laws by furnishing expressions that remain invariant under all transformations of co-ordinates. It is this, above all, that gives the tensor calculus its universal significance in mathematical physics.

Professor Lichnerowicz divides his exposition into two approximately equal parts, the first being devoted to the mathematical technique of the tensor calculus, the second to some of its more immediate and important applications. Assuming familiarity with ordinary vector concepts, the properties of n -dimensional vector spaces and sub-spaces are developed, while the important distinction between co-variant and contravariant vectors is clearly brought out. Chapter III deals with tensor algebra, discusses the outer and inner products, provides a criterion for tensor character, enunciates the rules for the addition, multiplication and contraction of tensors and introduces the fundamental Cartesian tensor. This is followed by an account of Euclidean space referred to curvilinear co-ordinates, together with the associated differential operators and the Christoffel symbols. Chapter V is concerned with Riemannian space and the basic operations relating thereto.

The second part opens with various examples of the application of tensors to dynamical systems and continuous media. This is followed by a chapter on the restricted theory of relativity, the Lorentz transformation and Maxwell's equations. The final chapter provides a brief introduction to the relativity theory of gravitation. To enable the student to acquire confidence in the formal manipulation of tensors, sets of exercises would have been useful. Considering the complication of the typesetting, involving special symbols and a mass of sub-scripts and super-scripts, the absence of misprints is noteworthy. Though the fundamental memoir of Ricci and Levi-Civita was issued as a separate reprint by Blanchard in 1923, it is not mentioned in the bibliography. Professor Lichnerowicz has selected his material with care and developed it with remarkable comprehensiveness in a small compass. His book forms quite the best available introduction to a subject of great and growing importance.

Engineering.

THE PRINCIPLES OF SCIENTIFIC RESEARCH.

PAUL FREEDMAN. 222, x pages. Macdonald & Co., Ltd., London, 15/-.

This is a book intended for the prospective research scientist and his employer. It is addressed to the former in order to explain to him something of the difficulties and disappointments he will assuredly experience in scientific research. It is addressed to the latter that he may receive a clearer picture of what can reasonably be expected of research and of the conditions conducive to the best results. It may be said at the outset that the book is written in a clear and attractive style, that it contains much that is worth reading and remembering, and that it also contains a fair amount with which one might disagree. This is no bad thing, for it will tend to stimulate thought, discussion or, preferably, both. Though entitled "The Principles of Scientific Research," it is concerned mainly with laboratory research in physics and chemistry. The special difficulties and techniques of biological and psychological research, for instance, are dealt with very lightly or not at all. Likewise the difficulties inseparable from experiments on a works scale are not mentioned. The treatment therefore suffers from certain limitations.

The first two chapters form a historical introduction. Chapter III is headed "Research and Philosophy," but the philosophy of science is hardly examined and the chapter is, in the main, an account of recent scientific discoveries and theories. In pages 62-66 the author, greatly daring, refers to the principles of Dialectical Materialism; but he fails to make clearer what these so-called principles really state or imply, whether they are in any case generally true and whether they are of the slightest use as an instrument of research. The average reader will probably conclude that they are valueless.

Chapter IV discusses the qualities which fit a man for scientific research, and the

planning of research is described in the two following chapters. A notable omission in these chapters is the planning of experiments on a works scale. In papermaking problems, for example, it is impossible adequately to reproduce the action of a Fourdrinier paper machine in the laboratory and sooner or later full-scale experiments in the mill become necessary to confirm or supplement laboratory tests. Such experiments can be made only at rare intervals, since they interfere with production and they are in any case very costly. Moreover, since all the variables involved are rarely under control or even known, interpretation of the results presents special difficulties.

Chapter VII deals with organisation of research, Chapter VIII with experimentation, and Chapter XI with accuracy and economy of effort. Chapter X discusses the use and meaning of statistical tests of significance of results, but the treatment is a little sketchy. In all work of a statistical nature, absolute correctness is unattainable. Only different degrees of probability of correctness can be considered, and the degree of probability accepted as "proving" conclusions varies widely according to the nature of the work, and the philosophy and emotional bias of the investigator and his critics. Much turns on what they consider to be antecedently probable or improbable and how the new conclusions fit into the scheme of existing knowledge. All research depends at some stage upon human testimony, and whether or not you accept the conclusions depends upon what credence you care to give to this testimony. In most research in physics and chemistry, the word of the investigator is hardly questioned, but in psychological work and above all in psychical research, the evaluation of human testimony forms one of the most difficult parts of the whole problem.

The last chapter, on "Patrons" (that is, financing of research) is in the reviewer's opinion the least satisfactory. Only a few points can be mentioned here. It is not true (p.207) that Research Associations "confine their publications to reports circulated among their members." On p.211 the author tells us concerning scientists and industrialists that "Their whole attitude to life has a quite different basis. To a scientist money is a means towards certain ends, the most important of these being the pursuit and advancement of science. To an industrialist, money is a means of making more money—money is to be made for its own sake." This is surely nonsense. An industrialist (who may simply be the owner of a small business employing a few men) makes a profit in order to buy food, clothing and shelter, to support a wife and family, maintain a home and garden, and do a hundred other things. A scientist accepts employment and earns a salary for precisely the same reasons. On p.212 and following, the author hopelessly confuses research, development and invention, three different forms of activity requiring different types of mind. Although the book is about research, the concluding pages are concerned more with invention. A good inventor is rarely a good scientist, and *vice versa*. Finally, the remarks on p.215 on secrecy and lack of interchange of research information are only partly true. In the paper industry, for example, research carried out by private firms is frequently published and there is a good deal of interchange of research and technical information. These firms know that Bill with Science can make a better paper; but Bill without Science can still make a saleable paper, whereas Science without Bill makes no paper at all!

It should not be thought from these several criticisms that this is a bad book. On the contrary, it deserves a wide circulation and even old hands at research will probably learn from it. The printing is good and the price normal for 1950.

V. G. W. HARRISON.