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Future Conference and Annual General Meeting.

Extrusion and Rolling Processes. This will be held at the University of Sheffield, on September 27th and 28th, and will include a visit to the B.I.S.R.A. laboratories. The Annual General Meeting will also be held during this Conference.

Obituary.

Mr. P. L. Bilham died suddenly on the 21st March, 1956. He was the Technical Director of the Symbol Biscuits Ltd.

News of Meetings.

At a Symposium on Principles of Penetrant Methods at the Institute of Physics, Friday, May 4th, 1956, arranged by the non-destructive testing group, the physics of the problems and the research needed for their solution were discussed. Several of our members contributed. A description of the various technical procedures for detecting cracks and holes in engineering components by the use of solutions containing fluorescent dyes and other substances, was given by Messrs. H. L. Carson (British Welding Research Association) and W. G. Cook (Rolls Royce Ltd.) and Dr. R. Schnurmann (Manchester Oil Refinery Ltd.). Sir Eric Rideal in opening the discussion spoke on the dynamics of liquid penetration into capillaries and into cracks closed at one end and the application of Henry's law of gas absorption. Dr. K. Weissenberg described experiments illustrating the production of homogeneous patterns of fatigue and rupture cracks. Dr. E. W. J. Mardles and Mr. A. de Waele spoke on specific effects observed in the spreading and penetration of liquids. Dr. W. H. Banks gave the results of spreading of liquids over a number of different metals and Dr. J. H. Schulman spoke on the highly-selective adhesion of amphipathic ionic and non-ionic molecules to metal surfaces.

The Fourth Rheological Symposium

held at Tokyo University, 2nd and 3rd June, 1955, under the joint auspices of the Chemical Society, the Physical Society and the Highpolymer Society of Japan.

Twenty-seven original papers were read on the following three subjects, (a) Thixotropy, (b) Surface films on Solids and (c) the Phenomenology and Molecular Theory in Rheology. In introductory remarks Mr. H. Kamble explained that thixotropy involved two rate processes, the breakdown and rebuilding of a structure in colloidal systems when the time lapse is comparable with observation times. Papers on the rheology of printing inks, aluminium stearate—peanut oil systems, of solutions of polyvinyl alcohol and other polymers were discussed from the standpoint of Thixotropy.

Prof. Y. Suge from experience gained on lubrication studies pointed out that the existence of small holes and cracks in a metallic solid surface might have an influential effect on the rheological properties of surface films. Several papers were read on the properties of thin films of paint, polymers, etc.

Mr. M. Yamamoto surveyed the subject of the molecular theory of visco-elasticity of amorphous highpolymeric substances, in particular, the relaxation time spectra at dynamical and statical ranges.

He criticized the theory of the "weakly connected network model" for the statical range, developed by Green-Tobolsky, Scott-Stein and Furukawa-Yamamoto pointing out that although such a model could interpret non-ideal rheological phenomena such as the Weissenberg effect and structural viscosity, yet it is still impossible for the model to indicate an expression for the relaxation time spectra at the range concerned. There were numerous papers on the visco-elastic properties of high polymers wool fibres, vulcanized rubber, etc.

FURTHER SUMMARIES OF PAPERS

read at the Symposium on the Rheology of Proteins, held at the Institute of Physics,
January 20th, 1956.

The Formation of Structures in Protein Solutions

By E. J. AMBROSE (Chester Beatty Research Inst.).

Solutions of material of high molecular weight separate into two phases in certain cases. Spontaneously ordered structures may then appear in the concentrated phase. Such behaviour is favoured by (i) the presence of large and rigid particles which are moderately anisotropic because their organisation is not readily disturbed by Brownian movement. (ii) the presence of weak forces of interaction between the particles and conditions which are nearly reversible, so enabling rearrangements of the particles to occur until the ordered state is produced.

Such conditions occur at critical concentrations in solutions of certain synthetic polypeptides with internally satisfied hydrogen bonds and non-polar side chains. Spherical structures with tangential orientation of molecules (spherulites) are observed.

Spherulites can also be observed in protein solutions but increasing anisotropy of the forces of interaction between the particles eventually leads to fibre formation, e.g. in the formation of fibrous insulin by hydrogen bond attachments between the particles. Such structures are particularly important in the case of nucleo-proteins, which occur in the nuclei of living cells. Fibres appear spontaneously in these solutions when a critical concentration has been reached. Interference methods of studying the solutions indicate that aggregation of particles occurs at a critical concentration, associated with an abrupt change of diffusion coefficient. The fibres are birefringent and show visual dichroism after staining with toluidine blue and neutral red.

In this respect nucleo-proteins differ from nucleic acid which only produces diffuse regions of birefringence at very high concentrations and gives no abrupt change of diffusion coefficient. The advantage of the more compact nucleo-protein particles over the more extended and flexible nucleic acid particles in producing spontaneously ordered structures can be seen in this case. These colloidal properties of nucleo-protein have been correlated, by interference microscope studies, with the behaviour of the living nucleus and their importance in relation to the maintenance of chromosome organisation has been confirmed.

Viscometric Investigation into the Influence of pH and Ionic Strength on Molecular Shape of a Structural Muscle Protein.

By A. WASSERMANN (University College, London).

A consistent explanation of the results of viscosity experiments can be given if it is postulated that actomysin in dilute solution is composed of flexible chains, the shape of which depends on pH and ionic strength of the solvent. The order of magnitude of the average distance between the chain ends of actomysin molecules is estimated. A detailed description of these experiments and calculations is given in the paper by M. L. R. Harkness and A. Wassermann in the Journal of the Chemical Society, 1954, page 1344.

Mechanical Properties of the Ovomucin Gel of the Egg

By J. BROOKS and H. P. HALE (Low Temp. Research Station).

Nearly one half of the white of a newly-laid egg consists of a gel (the thick white) in which a transparent phase is separated by a series of bands composed of microscopic fibres. When the egg is kept, the volume of thick white gradually decreases at a rate depending on the temperature. The mechanical properties of the gel were investigated by a method originally devised by Freundlich and Siefritz (Z. physikal. Chem., 104, 233, 1923) in which the displacement of a minute nickel sphere (diameter about 20 μ) inserted into the gel by means of a micro-manipulator is measured in a magnetic field. For stresses of short duration, the displacements were elastic in character in both the transparent phase of the gel and in its bands of fibres. The magnetic particle method provided a measure of the modulus of rigidity in arbitrary units. The indirect conversion of these values into absolute units was effected by means of a series of parallel measurements on gelatin gels of different concentrations using, on the one hand, the magnetic particle method and, on the other, a method (torsion between concentric cylinders) that enabled the rigidity to be measured in absolute units. The measurements were made on gelatin gels (0.4–1.0 per cent) with a similar range of rigidity to that encountered in thick white. Within this range of gelatin concentration, the rigidity changed much more rapidly with concentration than it does in more concentrated gels.

The rigidities of the two types of structure in the thick white were different but both of them were related to the proportion of thick white in the total white; i.e., as the volume of thick white in the egg decreased with time, there was a closely-related decrease in the rigidities of the gel structures that remained. As far as could be seen, the mechanical properties of the thick white seemed to be largely independent of the origin and treatment of the eggs except in so far as these determined the proportion of thick white.

SUMMARIES OF PAPERS

to be read at the Symposium on Rheological Research in the Textile Industry, held at the British Rayon Research Association, Heald Green Laboratories, Wythenshawe, Manchester 22
June 7th and 8th, 1956.

Relaxation Phenomena in Weaving

By K. GREENWOOD (British Rayon Research Association).

After a brief outline of the main functions of a loom, two types of fabric fault are discussed which are caused by relaxation and creep in the warp yarn and in the woven fabric during loom stoppages.

These faults consist either in a displacement of the weft threads in a direction perpendicular to the plane of the fabric (repping), or in incorrect spacing of these threads in the plane of the fabric.

1. *Repping*: To keep a weft thread in the plane of the fabric the tensions in the warp threads passing over and under it must be equal. During normal weaving the tension in each warp thread undergoes a cyclic change, and the tension cycles of different sets of warp threads are, in general, out of phase. Nevertheless the mean tension in all warp threads is the same, and hence the above condition is fulfilled. During a loom stoppage, however, there will be tension differences between different sets of threads. Their rates of relaxation will therefore differ, and when the loom is re-started their mean tensions will differ. This tension difference causes a displacement of the weft threads out of the plane of the fabric.

The effect of this displacement is to restore equality of tension between all warp threads after a short period of weaving. During this period, however, a permanent fault in the fabric has been created.

Methods of preventing this type of fault, and of measuring its intensity quantitatively are discussed, and a simple instrument is described which permits a comparison of the tensions in two threads or two sets of threads on a running loom.

2. *Incorrect Spacing*: In the power-loom, as distinct from the hand-loom, the spacing of the weft threads is critically dependent on the position of the cloth fell (i.e. the borderline between woven fabric and unwoven warp). During normal weaving the cloth fell is maintained in its correct position by the loom mechanism. During a stoppage, however, it is only held in position by the tension in the warp and the fabric. Relaxation and creep in both materials will therefore tend to cause a drift of the cloth fell, and when the loom is re-started the spacing of the weft threads is incorrect.

The effect of this incorrect spacing is to restore the cloth fell to its correct position after a short period of weaving. During this period, however, a permanent fault in the fabric has been created.

Methods of observing the drift of the cloth fell are described, and it is shown that the magnitude of the drift can be affected by certain features of the loom and by certain weaving practices.

Mathematical expressions are given which make it possible to predict the drift of the cloth fell from laboratory tests on the relaxation properties of the warp yarn and the woven fabric.

Nylon Fabrics

By A. M. THOMAS and P. HATFIELD (British Nylon Spinners).

The physical properties and the subjective properties of nylon fabrics are discussed. An attempt is made to correlate the physical properties of nylon with its crease resistance and recovery and with subjective properties such as handle, resilience, drape and softness in fabric form. A review is given of previous work on the possible correlation between physical and subjective properties for other fibres.

Nylon fabrics made from continuous filament yarns, and staple yarns spun on the silk, cotton, woollen and worsted systems are described. The importance of the spinning system, fabric construction, and crimp, as well as the physical properties, are discussed.

The effects of load, holding time and recovery time, fabric construction, washing, and heat setting on crease resistance and recovery of some nylon fabrics has been investigated. Load in the range 15 to 280 g.cm.⁻² has little effect on crease recovery. Increasing the holding time decreases the crease recovery of nylon fabrics when the crease recovery is measured after a short time (five minutes). However, the long time crease recovery of nylon fabrics is excellent, and the fabric behaviour is similar to the well-known visco-elastic properties of the yarn which show high percentage recovery from large extensions.

The effect of fabric construction e.g. filament denier, ends and picks, doubling, weave, particularly on the creasing properties, are discussed. In general, constructions which reduce the filament strains to a minimum during bending give the best recovery.

Heat setting has an important effect on fabric properties, particularly crease resistance and recovery. Because of the low moisture uptake of nylon, changes in relative humidity only have a small effect on fabric properties. Washing has a negligible effect on fabric properties, and repeated washing sometimes slightly improves their properties.

A discussion of Spontaneous Extension in Secondary Cellulose Acetate.

By H. J. WELLARD (British Rayon Research Association).

When partially oriented films of secondary cellulose acetate are immersed in suitable aqueous swelling agents they extend, often very greatly, without the application of any external stress. Extension without external stress can also be observed in rubber and nylon under suitable conditions but the effects are much smaller.

An outline is given of experimental results obtained with secondary cellulose acetate and possible explanations are considered. It is shown that further orientation of partially aligned crystalline or para-crystalline regions cannot account for the observed effects and

that changes in the configuration of individual cellulose acetate molecules must occur, increasing the effective length of each molecule. Some of this increase may result from the relaxation of molecules initially compressed to less than their statistical length but the greater part must represent a lengthening of statistically coiled molecules.

It is suggested that this is caused by the formation, by the absorbed water, of hydrogen bonds between adjacent rings of the secondary cellulose acetate chain. This inter-ring bonding must increase the rigidity of the chain in much the same way as does the intra-molecular hydrogen bonding in cellulose which is believed to be a relatively stiff polymer.

The conditions which a polymer must satisfy in order that spontaneous extension may occur are discussed.

The Effect of Treatment in Aqueous Phenol Solutions on the Physical Properties of Secondary Cellulose Acetate Filaments

By R. JEFFRIES AND H. J. WELLARD (British Rayon Research Association).

Fabrics which contain secondary cellulose acetate yarn are delustred commercially by treatment in hot aqueous solutions, usually solutions of phenol and soap. These treatments produce inside the filaments minute cavities which scatter light and reduce the lustre of the fabric. An undesirable result of the process is a weakening of the filaments which in some cases is considerable. This paper gives an account of an investigation into the effect of phenol concentration and of temperature on:—

(a) The mechanical properties of the yarn. The loss of strength is found to be accompanied by large changes in the load-extension characteristics of the yarn and is very largely independent of the presence of the delustring cavities.

(b) The molecular structure of the filaments. In most cases the loss of strength is accompanied by an increase in crystallinity and a decrease in orientation.

(c) The behaviour of the surface of the filaments during extension. An increase in the surface cracking is generally observed and, in some cases, the cracks are associated with pronounced "necking."

The results suggest that the loss of strength does not result directly from any of the other changes observed.

The Submicroscopic Structure of Drawn Yarns of 6.6 Nylon.

By M. F. CULPIN and K. W. KEMP (British Nylon Spinners).

The relationship between birefringence and draw ratio in yarns of 6.6 nylon is found to fit the results of the calculations given by Kuhn and Gr $\ddot{u}$ n (1942) over a wide range of draw ratio. Their assumptions concerning an assemblage of cylindrically symmetrical structural units have been extended in order to derive an expression for the distribution of intensity in the fibre X-ray diagram, and its variation with draw ratio. The theory is compared with experimental results, and it is suggested how the theory may be modified to improve the quantitative agreement with experiment.

The Rheological Requirements of Textile Printing Pastes

By W. G. HARLAND (British Cotton Industry Research Association).

The thickenings employed in the machine printing of textiles are rheologically complex fluids, whose viscosity coefficients fall with increase in rate of shear or shearing stress. In order to relate the viscosity of a colour paste to the quality of the resulting print, it is essential that the measurements of apparent viscosity should be made at the operative shearing stress. Previous work published from these laboratories has shown print definition to be controlled by the viscosity of the printing paste at a shearing stress of 4,500 dynes cm⁻², and levelness by the viscosity at low stresses of the order of 100 dynes cm⁻².

Since the above work was reported the Ferranti-Shirley cone and plate viscometer has become available. This instrument provides a rapid means of obtaining the viscosity of

printing pastes and thickenings over a wide range of rate of shear and shear stress, and this paper describes the results obtained with most of the commonly used thickeners at concentrations similar to those used in actual printing. Their flow properties are then examined in the light of the rheological requirements for satisfactory print definition and levelness. Some of the thickenings, notably the products based on starch, exhibit thixotropy. This behaviour can be misleading for the printer since pastes prepared from these thickeners are "thinned" by the shearing action of the furnishing roller and doctor blade. It is shown that the amount of thixotropic breakdown likely to be encountered can be estimated from the hysteresis loop formed by the flow curves obtained with increasing and decreasing cone speeds.

The viscosity behaviour of most thickenings varies with the condition of their preparation. This variation is considerable for those based on starch, so much so that, unless they are prepared under conditions that reproduce as closely as possible those used to prepare the bulk thickenings, the results may be quite misleading. Nevertheless it is shown that the variation in consistency (torque required for stirring under standard conditions) during the preparation of these thickenings provides useful information about their constitution and probable behaviour in the printing process.

Rigidity, Moisture and Fibre Structure

By R. MEREDITH (Dept. of Textile Industry, College of Science and Technology, Manchester).

It was shown by Peirce that the modulus of rigidity of cotton fibres was related in a simple way to the amount of water absorbed, if the absorbed water which produced the reduction in modulus was assumed to be that which was bound to the hydroxyl groups of the cellulose molecule. Later, Speakman examined the reduction in modulus of rigidity of wool fibres and showed that the fall in rigidity with absorbed water could be satisfactorily accounted for by applying a two-phase theory of absorption, but in this case the water responsible for the reduction in rigidity was that bound to the peptide groups of the protein molecule.

Measurements have been made of the effect of humidity on the modulus of rigidity of viscose rayon, silk, nylon and other fibres and the results have been examined on the basis of Peirce's two-phase theory of moisture absorption, modified to take into account the degree of crystallinity of the fibres. A linear relation between fall in rigidity and amount of "bound" water is found for viscose rayon, similar to cotton, whereas the behaviour of silk is similar to that of wool. The analysis of regain-humidity data for other fibres will be discussed.

RHEOLOGY ABSTRACTS

3299. **Summarized Proceedings of a Conference on the Structures and Textures of Metals—London, October, 1954.**

Brit. J. appl. Phys., 1955, 6, 377.

The annual Autumn Conference of the X-ray Analysis Group of The Institute of Physics was held in the Royal Institution, London, on 22 and 23 October, 1954. The first day's discussion centred on the structure of metals and alloys, whilst on the second day their texture was discussed. An evening lecture on dislocations was given by A. H. Cottrell. (82 refs.). A.

3300. **Summarized Proceedings of a Conference on Stress Analysis—Sheffield, September, 1955.**

Brit. J. appl. Phys., 1956, 7, 1.

The Ninth Annual Conference of the Stress Analysis Group of The Institute of Physics was held in the Stephenson Hall of the University of Sheffield on 28–30 September, 1955. Papers dealing amongst other things with design, plastic yielding, work at T.N.O. Delft, aircraft engine vibration, and photo-elastic investigations, were read, and are summarized in this report. A.

3301. **The Mean Velocity of Discrete Particles in Turbulent Flow in a Pipe.**

G. K. BATCHELOR, A. BINNIE and O. M. PHILLIPS. *Proc. Phys. Soc. B*, 1955, 68, 1095.

The axial component of velocity, averaged over a long time, of a material element of fluid in a straight circular pipe is shown theoretically to be equal to the discharge velocity defined as the discharge, averaged over a long time, divided by the cross-section of the pipe. This prediction was confirmed experimentally by injecting in turn into a water pipe a large number of solid spheres of different sizes having the same density as water. A satisfactory theory is developed to allow for the finite size of the spheres. The fluctuation in the time of travel of a particle between two fixed stations is examined, and it is shown how a few particles may be used to determine the discharge velocity within calculable limits of accuracy. A.

3302. **Rotational Viscometer for Rapidly Settling Suspensions.**

A. BHATTACHARYA and A. N. ROY. *Anal. Chem.*, 1955, 27, 1287.

A rotational viscometer of the concentric cylindrical type has been developed, the determinations being carried out in the turbulent range, and the data correlated as a plot of specific friction factor v. specific Reynolds number representing the calibration curve for this instrument. A.

3303. **Effects of Temperature on the Plastic Properties of Aluminium Crystals.**

A. H. COTTRELL and R. J. STOKES. *Proc. Roy. Soc. A*, 1955, 233, 17.

By changing the temperature of deformation, during tensile experiments on single crystals of aluminium, it has proved possible to separate reversible changes of flow stress with temperature from irreversible ones. Below 130°K the reversible change of flow stress is large; above room temperature it is hardly more than the change of elastic constants with temperature. These reversible changes are highly reproducible and, over a wide range of cold-worked states, proportional to the flow stress itself. The principal irreversible effect is a sharp yield drop, accompanied by a Lüders band, which appears

when a crystal is strained plastically at a high temperature (e.g. 300°K) immediately after being heavily cold-worked at a low temperature (e.g. 90°K). Intermediate annealing treatments reduce or eliminate this yield drop. Other experiments have proved that the yield drop is not a strain-ageing phenomenon but an extreme example of work softening, and that work hardening induced by preliminary deformation at the low temperature becomes unstable during plastic deformation at the high temperature and is rapidly removed. An explanation of the yield drop is suggested, based on recent theories of work hardening. It is proposed that, under the combined influence of stress and temperature, sessile dislocations at the heads of piled-up groups of dislocations become unlocked; the piled-up groups then partly collapse and many dislocations are released for slip. The reversible changes of flow stress are interpreted in terms of the intersection of dislocation lines. A.

3304. A Continuous-Flow Rotational Viscometer for Use with Downward-Settling Suspensions.

G. F. EVESON AND E. W. HALL. *J. of Sci. Instrs.* 1956, **33**, 110.

A rotational viscometer constructed of perspex is described capable of measuring the apparent viscosity of downward-settling suspensions of particles sized below 100 B.S. mesh, where the settling velocity of the particles relative to the dispersion medium is less than 0.2 cm. sec.⁻¹ Tests were made with suspensions of spherical particles of methyl methacrylate polymer. When suspensions are pumped round the systems, an equilibrium concentration of solids is reached after two or three minutes. The viscometer is calibrated with pure liquids of known viscosity. E.W.J.M.

3305. The Surface Viscosity of Soluble Films.

W. E. EWERS AND R. A. SACK. *Aust. J. Phys.* 1954, **7**, 40.

The surface viscosity of soluble films can be determined by measuring the velocity V_m of an element of surface moving along the centre-line of a rectangular trough under the influence of a constant bulk flow, $\bar{V}$, of solution along the trough. An equation is derived in which the ratio $\bar{V}/v_m$ is described accurately in terms of the dimensions of the trough, the viscosity of the solution, and the surface viscosity of the film absorbed at the air-water interface. This equation is based on the assumption that the surface pressure gradient along the trough is zero. When the surface pressure gradient is not zero, but is constant and of known magnitude, a second equation makes it possible to determine the surface viscosity.

Measurements of surface viscosity have been made with water, electrolyte solutions, and solutions of sodium dodecyl sulphate and of n-octanol. Author.

3306. Relation between the Initial Instantaneous Extension in Creep and Yield Stress and Coefficient of Work-hardening in Polycrystalline Metals.

P. FELTHAM, *Nature*, 1956, **177**, 632.

In a study of the creep of polycrystalline lead (99.99%) under constant stress in the range 20–105°C. it was found possible to measure the initial instantaneous extension with reasonable accuracy at the lower end of the temperature scale.

The tensile stress σ was related to the initial tensile strain ϵ by the work-hardening law characteristic of polycrystalline metals of cubic symmetry:

$$\sigma^2/\epsilon = X(T)$$

where $X(T)$ is the temperature-dependent coefficient of work-hardening. E.W.J.M.

3307. On the Flow of Rotating Fluid past Bodies in a Pipe.

L. E. FRAENKEL. *Proc. Roy. Soc. A*, 1956, **233**, 506.

Deals with the flow of a rotating, incompressible fluid through contractions and expansions of a pipe, or past bodies of revolution on the pipe axis. The flow fields are constructed from the stream functions of a ring source on the pipe wall or of a point

source on the pipe axis. These solutions involve wave motions when the angular velocity exceeds a critical value. The point-source solution is expressed in two forms, the first of which is useful some distance from the source, while the second displays more clearly the nature of the singularity and leads to a comparison of the corresponding doublet with Taylor's doublet solution (1922). Some streamline pictures and velocity distributions are presented, and the physical behaviour of a rotating fluid is discussed. A.

3308. Properties of Gases and Liquids Within the Range of Pressures Used in Industry.

E. U. FRANCK. *Chem.-Ingen.-Tech.*, 1955, 27, 473.

A review of thirty papers published during the last ten years on (1) pressure—temperature—volume ($P-M-V$) surface, (2) critical point between the gas and liquid region, (3) viscosity and heat conductivity, (4) coefficient of diffusion and gas density, (5) binary gas mixtures, (6) abnormal increase of vapour pressures of solids in compressed gases, and (7) solubility of solids in gases. A.

3309. On the Linear Work Hardening Rate of Face-Centred Cubic Single Crystals.

J. FRIEDEL. *Phil. Mag.*, 1955, 46, 1169.

The linear strain hardening observed after the easy glide region in face-centred cubic single crystals at sufficiently low temperature is explained by assuming that all the Frank—Read sources of the active slip system are in action, and form small active slip planes bounded on all four sides by Cottrell barriers. The initial easy glide region should occur before all the barriers are formed; the parabolic strain hardening appearing in the final stages would be related to a thermally activated breaking of the piled-up dislocations through the Cottrell barriers. A.

3310. Hypo-Elasticity and Plasticity.

A. E. GREEN. *Proc. Roy. Soc. A*, 1956, 234, 46.

A general theory of work-hardening incompressible plastic materials is developed as a special case of Truesdell's theory of hypo-elasticity. Equations are given in general co-ordinates for a single loading followed by one unloading, and attention is directed to materials for which the stress-logarithmic strain curve for unloading in simple extension is linear. Using a particular case of the corresponding constitutive equations for loading which is a generalization of that suggested by Prager, applications are made to a number of specific problems. A.

3311. Mechanical Conditioning of High Polymers.

P. U. A. GROSSMAN AND R. S. T. KINGSTON. *Aust. J. Appl. Sci.*, 1955, 6(4), 442.

A function of the ratio of irrecoverable strain to stress is introduced to describe the behaviour of a material subject to mechanical conditioning, where the principle of superposition is not applicable, and thus to extend the application of the theory of viscoelasticity. The relation between creep and stress relaxation is derived for three characteristic forms of this function, and it is shown that a comparison of creep and relaxation cannot furnish information on the existence of mechanical conditioning. Author

3312. The Structure and Properties of Paper.

H. G. HIGGINS, V. GOLDSMITH AND K. J. HARRINGTON. *Aust. J. Appl. Sci.*, 1955, 6(4): 496.

The rheological properties of initially wet handsheets made from eucalypt kraft pulps beaten to various degrees were examined at 20°C. and 65 per cent R.H. Measurements were made of (i) the stress-strain curve of the wet sheet at constant rate of straining, (ii) the stress relaxation, (iii) the development of tension within the drying sheet, at constant length, as a function of either time or moisture content, and (iv) the linear shrinkage of the paper as a function of time, either at zero stress or at a constant positive stress.

The tension developed upon drying to an arbitrary moisture content rises with the degree of beating. At zero stress the overall shrinkage and the rate of shrinkage in the initial stages of drying increase with the degree of beating. Under stress the length of the specimen passes through a maximum because both creep and shrinkage components contribute to the change in dimensions. The maximum length occurs earlier for higher degrees of beating. From a series of drying tests under constant load, it was found that shrinkage declined with increasing load. Data are presented on the mechanical conditioning of paper during drying, and its mechanism is discussed. Stress-strain curves of wet sheets do not show the marked change in slope characteristics of dry paper, presumably because interfibre movement is the only major straining mechanism operative. Relaxation effects can, however, be observed.

The experiments were extended to blends of eucalypt and pine kraft pulps. The drying tension, at constant length, at any arbitrary moisture content, was found to decrease with increasing proportion of eucalypt fibre. Author.

3313. An Investigation of Finite Strain in an Isotropic Material subjected to Hydrostatic Pressure and its Seismological Applications.

A. KEANE. *Aust. J. Phys.* 1954, 7, 322=333.

An attempt is made to reduce the generality of the usual theories of finite strain and to concentrate on the case of hydrostatic pressure. The method used has been based on the works of Murnaghan (1951) and Birch (1952), and yields a general relation giving the elastic constants in terms of the strain and the derivatives of pressure with respect to strain.

It becomes evident that a law in lieu of Hooke's law is needed to proceed with a mathematical theory; and so various elasticity equations in the literature are investigated to determine the special assumptions used to derive them from the present general equations. A linear relation between the second and third order elastic constants is then proposed and the resulting relation between pressure and density compared with Bridgman's experimental results for the alkali metals. It is found that the proposed law of finite hydrostatic strain agrees favourably with experiment and also with deductions from the atomic theory of solids.

The paper concludes with a few relevant remarks on the implications of the present theory to certain seismological problems. Author.

3314. A Survey of the Mechanical Properties of Some Fibre Building Boards.

N. H. KLOOT. *Aust. J. Appl. Sci.*, 1954, 5(1) 18.

Mechanical tests have been conducted on twenty makes of hardboard and ten makes of insulating board representing both overseas and local manufacture. A number of properties has been determined for the material in the normal dry condition and some on specimens soaked in water for twenty-four hours.

The variation in properties between makes of one type of building board was found to be large but variation within any one make was generally not greater than for most timber species. Soaking reduces the strength properties of both insulating boards and hardboards but the latter are relatively less affected.

It is suggested that the variability of each of the two main types of board, together with other factors discussed, indicates the need for setting up standard specifications for this material. Author.

3315. Weigh Bar Apparatus for Measuring Forces Resisting Ballistic Penetration.

J. M. KRAFFT. *J. Appl. Phys.*, 1955, 26 (6), 539.

Description of an apparatus employing the Hopkinson Bar Wire Strain Gauge technique for the measurement of projectile penetration forces as a function of time.

R.S.

3316. Surface Friction in Ballistic Penetration.

J. M. KRAFFT. *J. Appl. Phys.*, 1955, 26 (10) 1248.

Demonstration of the effect of surface contamination of the force of friction at high speed. A spinning projectile is fired at the end of a long bar. The torque has been measured separating the longitudinal force of a penetrating projectile from the torsional force wave resulting from the frictional adhesion which retards the projectile rotation. The force of friction accounts for about three per cent of the striking energy of a "mechanically clean" projectile. Any surface contaminants, not necessarily special lubricants, reduce this loss to less than one per cent. From the appearance of the "snow cap" on the projectile the author concludes that in the "mechanically clean" case the frictional energy loss is just sufficient to keep the surface at the melting temperature of the metal. He attempts to obtain indirect experimental confirmation and discusses the difficulties involved in distinguishing friction force from the longitudinal force necessary to deform the target. The author considers the approximate equality in area of the measured torque curve and the experimental curve using values of velocity and displacement obtained from the longitudinal force record as lending support to the "molten interface" hypothesis as the dominating feature influencing the force of friction between "mechanically clean" surfaces at high velocity.

R.S.

3317. The Viscosity of Cream in Butter Factories.

A. J. LAWRENCE. *Aust. J. Dairy Tech.* (1954), 9(4), 159.

For the design and selection of cream pumps and for the solution of cream pumping problems in butter factories, it is necessary to have data on the viscosities of the various types of cream likely to be encountered. Owing to the lack of data applicable to Australian butter factories, a limited investigation was undertaken to determine the viscosities of creams taken at different times of the year from various points in the cream flow lines of two butter factories. From the results it would appear that most of the creams to be dealt with in normal butter factory operations will have viscosities below 80 cp., average about 35 cp. Cooled pasteurized cream held overnight may reach 200 cp., and acid farm separated creams before neutralization may exceed 3000 cp., but mostly ranged between 100 and 1000 cp.

Author.

3318. On Viscoelastic Bodies Behaving Linearly.

J. MANDEL. *C.R. Acad. Sci. (Paris)*, 1955, 241, 1910.

In an extension of the theory of elasticity to viscoelastic bodies, retaining the principle of superposition, a modulus is replaced by a relaxation function (of time), and a reciprocal modulus by a flow function. The functions are related through their Carson (or Laplace) Transforms.

J. G. OLDROYD

3319. On the Flow of Maxwellian Bodies.

J. MANDEL. *C.R. Acad. Sci. (Paris)*, 1955, 241, 1550.

Examines the flow of a visco-elastic substance and makes an application to the case of large areas as for example of snow or clay soils.

A.

3320. Experimental Study of the Bending of a Circular Plate Subjected to a Uniform Pressure.

J. RABINOVITCH AND A. COMBETTES. *Cahiers de Phys.*, 1955, No. 61, 35.

The normal displacement in the centre of a uniform disk of metal, glass, or plastic is measured optically, by observation of Newton's rings, as a function of applied pressure in two experiments: one with the edge of the plate simply supported, the other with the edge clamped. The results indicate the effectiveness of different methods of clamping, and in favourable circumstances independent measures of Young's modulus and Poisson's ratio can be deduced.

J. G. Oldroyd.

3321. Stress Relaxation of Wool Fibres in Water at Strains of 5-20 per cent.
B. J. RIGBY. *Aust. J. Phys.* 1955, 8(1), 176.

A study has been made of the stress relaxation at fixed longitudinal strains of wool fibres immersed in water, in the post-yield region of their load-strain curves. The fibres were extended at controlled rates up to predetermined strains, particular attention being paid to the first few minutes of the subsequent stress relaxation. It was found that the relaxation curves so obtained could be represented by a sum of one, two or three negative exponentials, which could, in general, be simplified into two main processes, (a) a relatively fast relaxation of stress occurring in about the first 60 sec. and (b) a much slower relaxation. The activation energy of the fast process was found to be approximately 5 kcal/mol. Attempts to calculate activation energies for the slow process showed that the term corresponding to the energy was temperature dependent. Over the range 10-50 C, the values of this term were found to increase from about 22 to 27 kcal/mol. The fast and slow processes are respectively ascribed to the breakdown of weaker and stronger types of cross-linking bonds in the keratin. Author.

3322. Indentation Hardness of Glass as an Energy Scaling Law.
F. C. ROESLER. *Proc. Phys. Soc. B*, 1956, 68, 55.

A number of independently found empirical laws for the occurrence of Hertzian ring cracks are all equivalent and can be put in the form of an energy scaling law. It is suggested that this is the true explanation of the observed size effects, which would then lie in the dynamical similarity relations of geometrically similar stress fields and fracture surfaces. A.

3323. On the Characteristic of the Weakening Effect.
M. SATO. *Ark. Fys.*, 1955, 10, 37.

In connection with Benedicks' idea concerning the weakening effect on solid bodies due to wetting by liquids, the characteristic of this remarkable effect is discussed, assuming that the fracture should occur by consuming the strain energy stored in Taylor's elementary prism for fracture. A.

3324. The Wetting Effect on Quenched Carbon Steel Within its Elastic Limit
M. SATO. *Ark. Fys.*, 1955, 10, 45.

The change in Young's modulus of a quenched carbon steel due to wetting by several liquids is studied experimentally. It is found that the modulus is lowered by a group of liquids, while the reverse is the case with another group. The order of magnitude of this change is the same as that observed by Benedicks in his bending tensile test. Applying the experimental data obtained in the weakening effect for determining the surface tension of the specimen, it is found that the surface tension of this steel is c. 350 dyne/cm at 18-20° C. which agrees fairly well with Benedicks' result of determination. A.

3325. The Generation of Lattice Defects by Moving Dislocations, and its Application to the Temperature Dependence of the Flow-stress of F.C.C. Crystals.

A. SEEGER. *Phil. Mag.*, 1955, 46, 1194.

Treats in some detail the various mechanisms by which lattice defects are formed by moving dislocations. Particular attention is paid to the role of thermal energy in these processes and to the special features of extended dislocations in metals with low stacking fault energies. The results are applied to the temperature dependence of flow stress of such metals and are found to explain the temperature dependence observed in Cu quantitatively. Cu is known to have a low stacking fault energy. It is possible to deduce details about the mechanism of plastic deformation, in particular of the role played by the edge and the screw parts of dislocation rings under various conditions. The predictions of the theory on the nature of the lattice defects causing the increase of electrical resistance during cold work are shown to be borne out by recovery experiments. A.

3326. Automatic Balance for Measurement of the Strength of Glass Fibres.
D. SINCLAIR. *Rev. sci. Instrum.*, 1956, 27, 34.

The tensile strength and Young's modulus of glass fibres when bent into a loop are automatically measured. A differential transformer and servomotor are used to apply chain-weight as the tension in the looped fibre is increased by the loading motor. All measurements needed to calculate the tensile strength and Young's modulus are recorded on the drum chart driven by the loading motor. The maximum tensile stress in the looped fibre at the instant of break is proportional to the vertical motion of the recording pen, and the maximum strain is proportional to the rotation of the drum. A.

3327. Creep and Static Friction.

R. T. SPURR. *Brit. J. appl. Phys.*, 1955, 6, 402.

It is shown that the static friction between a soft metal hemisphere and a flat surface increases with the length of time the surfaces have been in contact and that this increase is due to creep. Such creep might account for the difference between static and dynamic coefficients of friction. A.

3328. The Laminar Flow of Streams of Suspended Particles.

T. V. STARKEY. *Brit. J. appl. Phys.*, 1956, 7, 52.

Experiments are described in which streams of coloured particles of mixed sizes suspended in water were admitted at a given point on the horizontal diameter of a tube placed horizontally, through which a steady flow of water was maintained. These coloured streams diverged on entry to the water and formed filaments in a horizontal plane. A study of the lateral movement of these filaments relative to one another, as the point of their admission to the tube and the rate of flow of water in the tube are varied, leads to the conclusion that lateral forces act on the suspended particles. Such forces, the magnitudes of which increase with particle size and with mean shear gradient, result from the motion of the particles in non-uniform velocity gradients. The motions observed lead directly to a simple flow mechanism, independent of particle configuration and orientation, which is shown to be qualitatively consistent with a number of well-established phenomena. A.

3329. The Formation of Cracks in Plastic Flow.

A. N. STROH. *Proc. Roy. Soc. A*, 1955, 232, 548.

The detailed mechanism by which a piled-up group of dislocations generates a crack is considered; it is suggested that a crack arises from short-range non-Hookian interactions of the dislocations at the head of the pile-up, and a model which takes some account of this is developed. The possibility of relieving the stresses round the pile-up by slip in the perfect lattice instead of by fracture is considered. Finally, it is shown that a crack can equally well be initiated by a smaller number of dislocations in each of several slip planes; this may be important in ductile materials. A.

3330. Density and Viscosity Measurements on Mercury and Very Dilute Potassium and Caesium Amalgams from the Freezing Point to 30°C.

R. SUHRMANN AND E. O. WINTER. *Z. Naturforsch.*, 1955, 10a, 985.

The temperature-dependence of viscosity is represented within 0.1% by $\eta = \eta_0 \exp q/RT$ with η_0 independent of T ; for pure Hg $q = 657.9$ cal, for K-amalgam of 0.191 at. % concentration $q = 714.6$ cal, and for the same concentration Cs amalgam $q = 690.4$. The results are correlated on the basis of regarding the alkali atoms as spheres, smaller than the holes which occur in the mercury, which produce a change in viscosity just as macroscopic spheres would. A.

3331. The Origin of Fatigue Fracture in Copper.

N. THOMPSON, N. WADSWORTH AND N. LOUAT. *Phil. Mag. (Ser. 8)*, 1956, Vol. 1, 113.

Describes metallographic observations of the development of fatigue cracks in copper. The specimens (polycrystal and single crystals) were tested in push-pull at 100 c/s. It was shown that the fatigue crack started in a slip band inside a single grain. An electropolishing technique showed changes in the character of the slip band after five per cent of the life had expired. Cracks more than one grain long were present when half the life had expired. It was confirmed that the fatigue life could be increased by preventing access of oxygen to the surface. The bearing of these observations on the problem of the origin of a fatigue crack is discussed. A.

3332. Fracture of Glass by Spherical Indenters.

J. P. A. TILLET. *Proc. Phys. Soc. B.*, 1956, 69, 47.

The production of ring cracks in silicate glass, by the impact of steel balls and by the application of a static load to spherical indenters, has been studied for a large range of indenter curvature. It has been found that in impact tests a greater height of fall is required to produce ring cracks than predicted by a critical stress criterion of fracture. In static experiments, two different relations between the force required to produce fracture and indenter size have been found. Below a radius of curvature of approximately 3.5 cm. the force is proportional to the radius and above this value to the square of the radius. Impact tests have also been carried out on a specimen of an organic glass-like material, with results similar to those of the impact experiments on silicate glass. A.

3333. The Role of Viscosity in the Formation of the Glassy State.

A. WINTER. *C.R. Acad. Sci. (Paris)*, 1955, 241, 1281.

A re-discovery of the fact that at the "softening" or "transformation" temperature of glasses the viscosity is of order 10^{13} poise. A.

3334. Dynamics of Polymer Molecules in Dilute Solution: Viscoelasticity, Flow Birefringence and Dielectric Loss.

B. H. ZIMM. *J. chem. Phys.*, 1956, 24, 269.

The problem of the motions of a chain molecule diffusing in a viscous fluid under the influence of external forces or currents is considered for a particular model. This model is a chain of beads connected by ideal springs. Hydrodynamic interaction between the beads is introduced in the approximate form due to Kirkwood and Riseman. It is possible to solve this problem exactly with the use of a transformation to a set of normal coordinates. The viscosity, birefringence of flow, and dielectric and tensile relaxation behaviour are calculated explicitly. The intrinsic viscosity in steady flow is somewhat different from the Kirkwood-Riseman result, and there is no change of viscosity with shear rate. The spectrum of relaxation times is similar to that found by Rouse and by F. Bueche, but has its maximum at a lower frequency than those obtained by Kuhn and Kuhn and by Kirkwood and Fuoss in other ways. A.