The annual meeting of the Society of Rheology will be held at The American Museum of Natural History, New York City, N. Y., Friday and Saturday, October 18 and 19, 1940 starting at 9:00 A. M. Our program committee, R. B Dow, chairman, has arranged an excellent program of fifteen papers. This program will be found on page 2. Abstracts of all papers on the program will be found on succeeding pages. It will be worth your while to attend all the sessions. By way of entertainment, the program committee has provided a lecture Friday at 8:15 P. M. by Dr. Roy Minor, Curator of The American Museum of Natural History on "Beneath the Seas for Museum Exhibits." A large audience is expected. It will probably be wise to come early to insure good seats.

The Annual Dinner of the Society of Rheology will be held at the Museum at 6:30 P. M. Friday. As in the past, it will be strictly informal, and will have no "after dinner" speeches. Come prepared to have a good meal. Your wife or lady friend will enjoy both the dinner and the lecture.

The official hotel is Hotel Standish Hall, 45 W. 81st Street, New York. This hotel is just across the street from the Museum. Rates start at $3.00 "single" and $2.00 each "double." Reservations should be made in advance by writing direct to the hotel.

Note: In this issue, the customary correlated reports of members of your Rheology Progress Committee will be found after the abstracts of program papers.

# PROGRAM

Society of Rheology

American Museum of Natural History at New York City

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October 18 and 19, 1940

Friday a. m.

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Registration 9:00-9:30

## INVITED PAPERS

1. 9:30-10:00    The Effect of Variation in Temperature on the Viscosity of Water from 10 to 60°C, G. Jones and T. W. Dakin, Harvard University.

2. 10:10-10:40    The Viscosity of Liquid Helium II, A. D. Misener, University of Toronto.

3. 10:50-11:20    The Transient Resilience of Some Fluids, J. M. Kendall, Geophysical Research Corp., Tulsa, Oklahoma.

4. 11:30-12:00    Rheological Problems in the Petroleum Industry, R. J. S. Pigott, Gulf Research and Development Co., Pittsburgh, Pa.

5. 12:10-12:40    The Creep of Metals, Parts III and IV, A. Nadai, Westinghouse Research Laboratories, East Pittsburgh, Pa.

Friday p. m.

6. 2:30- 2:45    Some Relations of Flow and Physical Properties wth Formulation in Cellulose Acetate Plastic. W. E. Gloor, Hercules Powder Co., Parlin, N. J.

7. 2:55- 3:10    Flow Relationships of the Thermoplastics. C. A. Nash, Bakelite Corp., Bloomfield, N. J.

8. 3:20- 3:35    The Viscosity of Russian and Rumanian Lubricating Oils at High Pressure. R. B. Dow, J. H. McCartney, and C. E. Fink, The Pennsylvania State College.

9. 3:45- 4:00    The Viscosity of Aqueous Solutions of Non-Electrolytes, R. H. Ewell and P. E. Hardy, Purdue University.

| 10. | 4:10- 4:25 | Viscosity, Diffusion and the Structure of Liquids, W. E. Roseveare, R. Powell, and H. Eyring, Princeton University. |

| | 4:45- 5:45 | Business meeting and social hour. |
| | 6:30- 7:30 | Annual dinner. |
| | 8:15 | Invited lecture by Dr. Roy W. Minor, Curator, American Museum Natural History, "Beneath the Seas for Museum Exhibits." |

## Saturday a. m.

| 11. | 9:15- 9:45 | The Ideal Law of Mixtures for Viscosity. R. H. Ewell and H. S. Lecky, Purdue University. |
| 12. | 9:55-10:10 | The Rheology of Blood. A Review. E. C. Bingham and R. R. Roepke, Lafayette College. |
| 13. | 10:20-10:35 | Measurement of Viscosity with the Bingham Viscometer. J. E. Swindells, National Bureau of Standards. |
| 14. | 10:45-11:00 | Relaxation of Metals at High Temperatures. W. E. Trumpler, Jr., Westinghouse Research Laboratories, East Pittsburgh, Pa. |
| 15. | 11:10-11:25 | Dependency of Stress-Strain Curves for Rubber on Temperature and Rate of Steretching. R. L. Anthony, R. H. Caston and E. Guth, University of Notre Dame. |
| | 11:35-12:00 | Supplementary program.* |
| | 12:00-12:15 | Report of Committee on Definitions and Nomenclature. R. L. Peek, Jr., Bell Telephone Laboratories, New York City. |

## Saturday p. m.
Tour of American Museum of History.

# THE EFFECT OF VARIATION IN TEMPERATURE ON THE VISCOSITY OF WATER FROM 10 TO 60°C.

by

Grinnell Jones and Thomas W. Dakin
Harvard University

The photo-electric cell method of timing the efflux of an Ost-

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* Supplementary papers have already been received from J. R. Coe, of U. S. Bureau of Standards and from P. J. Flory of the S. O. Development Co.

wald type of viscometer, as it has been developed by Jones and Talley, has with modifications been used to measure the viscosity of water at 10, 20, 30, 40 and 50 and 60°C. relative to the viscosity at 25°C. Corrections have been applied for the effect of the change in the surface tension of water with temperature, for the kinetic energy, and for the change in the hydrostatic head effected by the thermal expansion or contraction of the water in the instrument, and for the thermal expansion or contraction of the viscometer itself. A water thermostat controllable to ±0.001°C. respectively at all the temperatures indicated was necessarily developed, to keep the temperature variations of the viscosity within the limits of sensitivity of the method. The temperature scale was fixed by a platinum resistance thermometer.

Although absolute measurements have not been attempted, it is believed that the temperature coefficient of the viscosity of water has been determined with greater precision than in any previous measurements.

## THE VISCOSITY OF LIQUID HELIUM II
by
A. D. Misener
University of Toronto

The low temperature modification of liquid helium which exists from absolute zero up to 2.19°K, apears to posses flow properties different from any other known liquid. Different types of viscosity measurement, which yield consistent results with ordinary liquids, give very conflicting results with this liquid. Contrary to usual experience the average velocity of flow through very fine channels increases as the channel cross-section is decreased. These flow phenomena have an intimate connection with other transport properties of liquid helium. These will be described briefly and with their added information a picture of the flow mechanism of liquid helium will be built up. This picture leads to the interesting conclusion that in liquid helium II the anomalous heat energy is not distributed uniformly amongst all the atoms of the liquid but is contained in a number of excited atoms which may have a limited free translational motion inside the liquid rather like the electrons in a metal.

## THE TRANSIENT RESILIENCE OF SOME FLUIDS
by J. M. Kendall
Geophysical Research Corp., Tulsa, Okla.

An apparatus was built for investigating certain transient elastic phenomena in fluids which can be observed only within a very short

4.

interval of time after the application of stress to the fluid. The term "transient resilience" will be applied to these phenomena. The apparatus is essentially a concentric cylinder viscometer of very small dimensions. A coil is fastened to the moving cylinder and placed in a strong magnetic field. An impulse of a few microseconds duration is obtained from a condenser discharging through this coil. The moment of inertia of the moving cylinder must be made very small in order that the fluid be subjected to a very sudden shear. The motion of the cylinder is recorded photographically on a rotating drum. The apparatus is suitable for fluids in the viscosity range of 0.1 to 50 Poises.

About twenty fluids were investigated. A good many solutions of long chain molecules in low viscosity solvents were found to have pronounced transient resilience. The relaxation time for these solutions ranged from less than one-thousandth of a second to several hundredths of a second. It was found that the transient resilience increases with the concentration of the solution. The most dilute solution found to have a detectable transient resilience had a viscosity of 0.25 Poises. Some emulsions were found to have both appreciable transient resilience and a finite yield strength, thus indicating that they should be classed as plastics rather than fluids. Simple fluids, including mineral oil, which are strictly Newtonian show no trace of transient resilience.

An attempt is made to explain transient resilience as resulting from the structure formed by the long chain molecules in the solvent.

## RHEOLOGICAL PROBLEMS IN THE PETROLEUM INDUSTRY
by
R. J. S. Pigott
Gulf Research Laboratory, Pittsburgh, Pa.

## THE CREEP OF METALS, PARTS III AND IV
by A. Nadai

### Abstract

Solids under stress, particularly under the prolonged action of stress deform permanently at high temperatures although the loads or stresses in them may be comparatively small. The creep of metals has obliged engineers to design their machines such as steam turbines or apparatus used in the petroleum or chemical industry, which must operate at high temperatures so that the total distortion or the sum of the elastic deformation and of the creep which will accumulate within the service time shall not exceed the permissible amounts.

In what follows ideas for predicting quantitatively the slow deformations of the metals at high temperatures under given conditions and some results of experimental investigations covering a period of several years will be reported. The transition from a purely elastic state of equilibrium to one in which the permanent strains are of the same order of magnitude as the former ones, will be studied under the precise conditions of a constant strain rate or of a relaxation test. Equipment for these two tests and results which were obtained with it will be described. The hyperbolic sine law connecting stress with the permanent rate of strain and other plausible speed-laws will be considered.

## SOME RELATIONS OF FLOW AND PHYSICAL PROPERTIES WITH FORMULATION IN CELLULOSE ACETATE PLASTICS

by

W. E. Gloor, Hercules Powder Co.

Parlin, N. J.

Data are presented showing flow and physical properties of cellulose acetate plastics made using five plasticizers (previously described by Kirkpatrick before the Society of Rheology) with cellulose acetates of 2.3 and 2.6 acetyl groups per $C_6$ unit. Single plasticizers exert specific effects on flow and physical properties of the plastics. Mixtures of such plasticizers give plastics with properties which may be predicted by a simple proportion based on the amount of each plasticizer used. Results of Rockwell hardness, elastic modulus, impact strength, and water absorption tests of molded are discussed. No general relation is found between flow properties of the plastics at molding heats and physical properties at room temperatures. An attempt is made to relate these results to the criteria for high elasticity set up by Houwink.

## FLOW RELATIONSHIPS OF THE THERMOPLASTICS'

by

C. A. Nash, Bakelite Corporation

Data covering relationships of pressure and temperature to flow of polystryrene, methacrylate, cellulose acetate, ethyl cellulose and aceto-butyrate as determined by the Rossi-Peakes Flow Tester will be discussed.

Effect of temperature change (pressure constant) and pressure change (temperature constant) will be given. A brief discussion of the different possible methods of determining flow will be described. Effect of conditioning samples before testing will be covered briefly.

# THE VISCOSITY OF RUSSIAN AND RUMANIAN OILS
## AT HIGH PRESSURE

by

R. B. Dow, J. S. McCartney, and C. E. Fink, The Pennsylvania
State College, State College, Pa.

The viscosity characteristics of four Russian and three Romanian oils have been studied at 100°, 130°, and 210°F at pressures ranging from atmospheric to 50,000 lbs/in² by methods described previously. Complete chemical and physical analysis of the oils was made in order to attempt to correlate their properties with viscosity and its change with pressure and temperature. The coefficient of viscosity at a given pressure and temperature is some power of the coefficient at standard conditions, the power being a complicated function of pressure and temperature. It is suggested that the ratio $\log \eta / \log \eta_0$, ($\eta$ is the coeff. at a certain pressure and temperature and $\eta_0$ is the coeff. at atmos. pressure and the same temperature), is more significant in correlating viscosity change with other factors than any of the other common means of representation, eg. $\log \eta/\eta_0$, especially when it is applied to a homologous series of liquids. The correlation with molecular weight is emphasized since it permits certain generalizations to be made regarding viscosity and structure. $\log \eta / \log \eta_0$ decreases with increase of molecular weight at a constant pressure and temperature for Russian and Rumanian oils, but more slowly than for Pennsylvania oils. The ratio increases with pressure at a greater rate for the former oils. These are attributed to the greater number of branch-chain paraffins per ring in the molecules of the latter type of oils. The temperature coefficient of viscosity of Russian and Romanian oils at various pressures is discussed and compared with that of certain Pennsylvania oils.

# THE VISCOSITY OF AQUEOUS SOLUTIONS OF
## NON-ELECTROLYTES

by

Raymond H. Ewell and Paul E. Hardy

Department of Chemistry, Purdue University, Lafayette, Ind.

New data are presented on the viscosity of the following solutions:

    water + ethylene diamine
       " + ethyl lactate
       " + butylamine
       " + diethylamine
       " + ethanolamine
       " + acetonitrile
       " + formamide

These data are combined with data already in the literature on aqueous solutions of alcohols, acids, esters, ethers, ketones, amines, etc., in a systematic survey of the field. The outstanding generalization drawn is that the addition of any water soluble liquid **decreases the fluidity** up to about 10 per cent of the solute. This is true for very viscous liquids such as glycerol whose viscosity is many times that of water, and for very fluid liquids such as acetone whose viscosity is much less than that of water. Evidently the addition of small amounts (up to about 10 per cent) of any water soluble liquid increases the number of hydrogen bonds present.

## VISCOSITY, DIFFUSION AND THE STRUCTURE OF LIQUIDS

W. E. Roseveare, Richard Powell, Henry Eyring
Princeton University

A theory of holes, or empty lattice sites, in liquids enables one to gather into a single consistent picture the rate processes (viscosity and diffusion) and the thermodynamic properties of liquids. The proportionality between volume and fluidity, observed for so many liquids, has a natural explanation in this theory. Exceptional cases are noted and treated theoretically. The theory of melting here developed suggests the tendency of liquids to be equally fluid at their melting point. Certain exceptions to this rule are explained. The significance of the low temperature dependence of the viscosity of liquids at constant volume is interpreted in terms of the theory of Absolute Reaction Rates. The viscosity law for mixtures is considered.

## THE IDEAL LAW OF MIXTURES FOR VISCOSITY

Raymond H. Ewell and Herbert S. Lecky
Department of Chemistry, Purdue University, Lafayette, Ind.

On the basis of the reaction rate theory of flow in liquids the most reasonable forms of the ideal law of mixtures for viscosity are

$$\phi = N_2 \phi_2^\circ + N_2 \phi_2^\circ$$

if the elementary flow process is considered to be monomolecular, or

$$\phi = N_2^2 \phi_2^\circ + 2N_2 N_2 \sqrt{\phi_1^\circ \phi_2^\circ} + N_2^2 \phi_2^\circ$$

if the elementary flow process is considered to be bimolecular. However, these two relations do not differ very much unless the fluidities of the components differ greatly. In order to make an experimental study of these relations the viscosities and densities were measured for over twenty mixtures of liquids, such as $CCl_4$, $CBr_4$, $SnCl_4$, $SnBr_4$, $CS_2$, $C_6H_6$, $CHCl_3$, $CHBr_3$, et al. For most mixtures the fluidity deviation from ideal ($\Delta \phi$) is in the same directon as the vol-

ume on mixing ( $\Delta$ V), which is consistent with the fact that the viscosity of pure liquids is primarily a function of the volume. If the heats of vaporization (and therefore the intermolecular attractive forces) of the components differ greatly, an additional negative deviation in the fluidity is superimposed on the volume effect, such that these mixtures may have $\Delta \phi$ and $\Delta$ V of opposite sign.

## THE RHEOLOGY OF BLOOD. A REVIEW
by
Eugene C. Bingham and Raymond R. Roepke
Lafayette College

While the results of a number of studies show conclusively that blood does not follow Poiseuille's law, it does not appear possible to determine from these studies the exact nature of the laws which do govern the flow of blood. From a review of the literature it appears evident that the apparent fluidity of blood is dependent primarily on the fractional volume of red blood cells, on the concentration of proteins in the plasma, on the temperature and on the conditions of flow, namely the rate of shear and the diameter of the capillary. Much of the work reported in the literature is of little or no value because it was based on the assumption that the flow of blood follows Poiseuille's law.

Although Poiseuille, in his observations n the flow of blood in the circulatory system of living animals, noted a marginal zone of cell-free, mobile plasma in the blood vessels, it was not until many years later that the effect of this cell-free layer of plasma on the apparent fluidity of blood was taken into consideration. Preparations are being made for studying the laws of flow of blood and plasma under various conditions.

## MEASUREMENT OF VISCOSITY WITH THE BINGHAM VISCOMETER
by
James F. Swindells
National Bureau of Standards, Washington, D. C.

A technique is described by which measurements may be made with an accuracy of about 0.1 per cent relative to a chosen value for the absolute viscosity of water. The range of viscosities which may be covered conveniently is from 0.5 cp. to 2000 cp. A discussion of the problems which arise in the use of the Bingham viscometer includes:

1. The evaluation of the constants of the instrument.
2. The elimination of drainage errors.
3. The measurement of the internal head in the instrument.

4. A correction to be applied in measuring the viscosity of petroleum products due to the change of viscosity with pressure.

## RELAXATION OF METALS AT HIGH TEMPERATURES
by
W. E. Trumpler, Jr.

### Abstract
The behavior of metals, especially the high strength alloy steels, under continuous loading at elevated temperatures has become a subject of increasing importance in industry due to high temperature application in the field of power generation. Much experimental work has been done on the creep of metals and the long-time creep test is the standard means of rating resistance to slow deformation of metals under tensile stress.

In engineering practice, however, cases frequently are found in which the total strain and not the stress remains constant. In what has become known as relaxation, an initially pure elastic strain gradually is transformed into a permanent strain while the length of the bar remains unchanged. Several years ago some new apparatus was designed and built primarily to duplicate the above conditions in connection with the study of bolt materials for steam turbines. The unusual accuracy and exceptionally good test results obtained from the automatic relaxation machine during more than two years of operation indicate that the type of test may well become a means of comparison as standard as a creep test and at a great reduction of testing time.

## DEPENDENCY OF STRESS-STRAIN CURVES FOR RUBBER ON TEMPERATURE AND RATE OF STRETCHING
by

Robert L. Anthony, Ralph H. Caston, and Eugene Guth
Department of Physics, University of Notre Dame

Conflicting results are given in the literature on the dependency of the stress-strain curves upon temperature. To settle this problem, the various methods proposed to obtain equilibrium stress-strain curves were critically re-investigated. It was found that truly reversible isometrics always show an increase of stress with rising temperature at constant extensions as long as no crystallization sets in—in agreement with the statistical theory of rubber elasticity. The isothermal stress-strain curves show good agreement with the theoretical curves derived by James and Guth (presented at the Detroit meeting of the A. C. S., September 1940).

Confirming and extending results of Ornstein, et al, and espe-

cially of Williams, we see that the crystallization reveals itself by an apparent hysteresis which, however, is not connected with any flow or permanent set. Upon changing the rate of stretching, two limiting cases are shown to exist: adiabatics for high and isothermals for low speeds. The standard speed used in testing (20 inches per minute jaw separation) corresponds neither to an adiabatic nor to an isothermal, but to an intermediate case, lying closer to adiabatics. A photographic method was developed to obtain simultaneously the stress-strain curve and Poisson's ratio. For pure gum compounds and moderate extensions Poisson's ratio was found to be one-half (incompressibility) in agreement with previous, but less direct, measurements.

## REPORTS FROM MEMBERS OF THE
## RHEOLOGY PROGRESS COMMITTEE
## RHEOLOGY OF RUBBER — REVIEW

A most interesting recent article in the field of rheology of rubber is that by L. R. G. Treloar, "Elastic and Plastic Flow in Raw Rubber", (Trans. Far. Soc., **36**, 538, 1940). The primary purpose of this work was to distinguish between the elastic and plastic deformation when raw rubber is stretched, and to measure the two effects separately. The "elastic" deformation was taken to be that part which is recovered when the stretching force is released, and the "plastic" deformation, the part that is not recovered. The author tried different recovery procedures and chose that which led to the greatest recovery. The final step in this method consists in swelling the sample in a mixture of benzol and alcohol and evaporating to dryness.

The surprising results of these experiments were that after being stretched for one hour at 25°C. from zero to 650% elongation, all samples recovered completely their original length, except those that were stretched between 150 and 400%. Even those showed permanent set or plastic effects of only 5% or less. This complete or nearly complete recovery is remarkable in view of the fact that during the stretching period of one hour the tension dropped by one-third of its initial value.

Samples stretched for one hour at 50°C. showed much greater plastic effects, but again there was a maximum, occurring in this case at the stretching length of 450%.

The author points out in a competent discussion of his experiments that the results indicate strongly the existence in raw rubber of a 3-dimensional net work which involves only a fraction of the material, but which persists through the stretching treatment im-

posed. After release, this net-work is able, under favorable circumstances, to pull the rest of the material in the sample back to its original shape, in spite of weaker and less stable attachments that are built up during the stretching period.

The reviewer points out that these experiments show that much can still be learned about rubber by simple experimental methods in the hands of a clever and intelligent investigator. However, this reviewer would like to add that, in his opinion, our knowledge of the structure of rubber is increasing rather slowly, and the rate of increase will remain slow until a group of individuals or laboratories with the proper facilities adopts a cooperative program of research to investigate all the important physical and chemical properties of a selected group of typical samples of raw and vulcanized rubber.

Another recent development of interest in the rubber field lies in the use of rheological measurements of mixes of carbon black in raw rubber to grade the carbon blacks. The mixes must be made under carefully controlled conditions, but the measurements indicate not only the processing quality of the carbon blacks in raw stock, but also the abrasion rating in cured tread stocks. ("Effect of Particle Size on Processing Properties and Abrasion Resistance of Carbon Black in Tread Stocks", G. L. Roberts, India Rubber World **101**: 39, 1940).

<div align="right">M. M.</div>

## THEORY

Relation between the viscosity of a liquid and the vapor concentration. G. W. Marks. J. Phys. Chem. **43**, 549-59 (1939). An empirical relation $\phi$ const. $xC^m$, where C is the molecular concn. in the vapor and m is a constant, is demonstrated for a large group of liquids. Combining this with the Clapeyron eqn. and integrating, M. gets $\log \phi_1 / \phi_2 = m \left[ 0.0522 \Delta H (1/T_1 - 1/T_2) - \log T_2 / T_1 \right]$ where $\Delta H$ is the heat of vaporization.

Viscosity of liquids. A. H. Nissan and L. V. W. Clark. Nature 143, 722-3 (1939). When $\log n$ is plotted against $T_B/T$ ($T_B$ is absolute B. P.), anll the n-parafins from butane to octadecane fall on the same curve. Since the plot is not exactly a straight line, the constant B in $n = A \exp B/T$ varies with the temp. Also, if $n_B/n_T$ (viscosity at absolute B. P. / viscosity at absolute temp. T) is plotted against $T/T_B$ for various liquids, associa-

ted liquids fall in the upper region of the graph, metallic liquids in the lower region and normal liquids in between.

Relation between fluidity, temperature and chemical constitution of pure liquids. E. C. Bingham and S. D. Stookey. J. Am. Chem. Soc. **61**, 1625-30 (1939). The fluidity of a liquid is described by $\varphi/T = a + bT$, where a and b are constants of the liquid. For 20 liquids the aver. deviation from the observed values is 0.15%. The behavior of six homologous series can be represented by $\varphi/T = A_s + \alpha\,T.10^{\beta/m - \gamma/m^2}$, where $A_s$, $\alpha$, $\beta$, and $\gamma$ are constants for a given series, and M is the mol. wt. The last equation is valid up to 10 carbon atoms. The behavior of the alcohols and water is anomalous.

The temperature variation of viscosity in nonpolar and dipolar inorganic liquids. S. T. Bowden and A. R. Morgan. Phil. Mag. **29**, 367-78 (1940). The viscosities of a number of inorganic liquids: $SiCl_4$, $SnCl_4$, $PCl_3$, $AsCl_3$, $BiCl_3$, $S_2Cl_2$, $POCl_3$, $SOCl_2$, $SO_2Cl_2$ are shown to follow the exponential relation $n = A\exp B/T$, which had been tested principally with organic liquids heretofore.

Viscosity of liquids and saturated vapors at high temperatures and pressures. K. Khalilov. J. Exptl. Theoret. Phys. (U. S. S. R.) **9**, 335-45 (1939). Measurements of both liquid and vapor in the critical region for ethanol, n-propanol, ethyl formate, propyl formate, heptane, diphenyl ether. A number of fairly obvious generalizations are drawn from the results.

Viscosity and molecular structure. H. Mark and R. Simha. Nature, **145**, 571-3 (1940). A timely review, largely on large molecules.

Theory of viscous flow reactions for chain-like molecular substances. F. Eirich and R. Simha. J. Chem. Phys. **7**, 116-21 (1939). The investigations of Eyring and Ewell are extended to new data on esters of formic, acetic, nonylic, nonylenic and oleoic acids. The ratio $E_{vap}/E_{vis}$ varies with temperature, usually decreasing with increasing temp., but it increases for the nonylic esters and is practically constant for the oleic esters. For long molecules both $E_{vis}$ and the entropy factor are temperature dependent and therefore the exponential law $n = A\exp B/T$ may not be followed over wide temperature ranges. (The reviewer believes

13.

that both these quantities are temperature dependent for small as well as large molecules and that their conpensation to follow the simple exponential law is the usual conpensating effect of energy and entropy to give a constant free energy).

Viscosities of linear polyesters. An exact relation between viscosity and chain length. P. J. Flory. J. Am. Chem. Soc. **62,** 1057-70 (1940). The viscosities of molten linear polyesters can be represented either by the equation log $n = A + C' M_w^{1/2}$, where $M_w$ is the weight average mol. wt. and A and C' are constants, or by the equation log $n = A + CZ_w^{1/2}$, where $Z_w$ is the weight average chain length. This conclusion results from the measurement of the viscosities of molten polyesters having average mol. wts. in the range 200 to over 10,000. The viscosity of mixtures of 2 polyesters, one having low and the other a high average mol. wt. agree with the formula using the weight average chain length, indicating that the second formula does not depend on the distribution of species in the polymer. The value of d ln $n$/dT is independent of the average mol. wt., and its magnitude is not many times greater than that found for the corresponding monomers. The elementary process responsible for viscous flow must consist of displacement of only a small section of the chain, which process is probably the same for polymers of all sizes. The utility of the viscosity-chain length relation as a simple and accurate means of determining mol. wt. is discussed.

Effect of temperature and specific volume on the viscosity of liquids. III. W. R. van Wijk, J. H. van der Veen, H. C. Brinkman and W. A. Seeder. Physica **7,** 45-46 (1940). Results of measurements at 1500 atm. and from 0 to 150°C. are shown tabularly and graphically for $C_3 H_8$, $C(CH_3)_4$, $CCl_4$ and n-$C_{18} H_{37}$ OH.

Measurement of viscosity in the critical region. Ethylene. S. G. Mason and O. Maass. Can. J. Research **18,** 128-37 (1940). A precision oscillating disc viscometer was constructed with a view to studying the viscosity of systems at the crit. temp. and crit. pressure. A new method of computing logarithmic decrements is described, and a number of results obtained with $C_2 H_4$. Of particular interest is the transition in viscosity of an isochore through the crit. temp.

The effect of an electric field on the viscosity of liquids. H. Menz. Ann. Physik **34,** 740-60 (1939). Application of electric field to ethyl ether, carbon tetrachloride, benzene and chloro-benzene

decreased the viscosity, the effect diminishing with increasing frequency. The effect, which never exceeded 10%, is the resultant of two factors: decrease in viscosity due to ohmic heating and increase due to decreased mobility of streaming molecule-ions.

<div align="right">R. H. Ewell</div>

## THE FLOW PROPERTIES OF BITUMINOUS MATERIALS (III)

At the June, 1940 meeting of the American Society for Testing Materials varied information of interest to bituminous technologists was announced.

Proposed revised tentative definitions of terms relating to rheological properties of matter were presented for publication as tabulated below:

| | |
|---|---|
| Consistency: | That property of a body by virtue of which it tends to resist deformation. |
| Plasticity: | That property of a body by virtue of which it tends to retain its deformation after reduction of the deforming stress to its yield stress. |
| Elasticity: | That property of a body by virtue of which it tends to recover its original size and shape after deformation. |
| Liquid: | A substance which undergoes continuous deformation when subjected to shearing stress. |
| Simple Liquid: | A liquid in which the rate of shear is proportional to the shearing stress. The constant ratio of shearing stress to rate of shear of a simple liquid is the viscosity of the liquid. |
| Complex Liquid: | A liquid in which the rate of shear is not proportional to the shearing stress. |
| Solid: | A substance which undergoes permanent deformation only when subjected to shearing stress in excess of some finite value characteristic of the substance (yield stress). |
| Plastic Solid: | A substance which does not deform under a shearing stress until the stress attains the yield stress, when the solid deforms permanently. |

<div align="center">15.</div>

Elastic Solid: A substance in which, for all values of the shearing stress below the rupture stress (shear strength), the strain is fully determined by the stress regardless of whether the stress is increasing or decreasing.

In addition, two papers dealing with the flow properties of bituminous materials were read, one by Traxler,[1] Schweyer,[1] and Romberg[1] on "The Rheological Interpretation of Asphalt Tests", and another by Ford[2] and Arabian[2] on "The Measurement of the Deformation Properties of Asphalts".

In the first paper, the authors show by comparison of penetration results with consistency in poises that the penetration test is not satisfactory for the evaluation of rheological properties. Also it was pointed out that other tests such as Ring and Ball Softening Point, Ductility, float and such emperical tests are inadequate for the quantitative evaluation of flow properties. It was suggested that asphalts exhibiting complex flow should be determined at some standard rate of shear (possibly 0.001 reciprocal second and at one other suitable rate of sheer, by means of the rotating cylinder viscometer. The writer believes this paper to be a valuable addition to the excellent contributions previously made by Traxler and coworkers in this field.

In the second paper, it was pointed out that penetration and softening point tests give misleading information, particularly for asphalts which have elastic properties. The authors advocate the use of the rotating cylinder viscometer since this type of instrument permits the separation of elastic and viscous effects, and they report the development of a simple instrument designed for routine use. In this instrument the sample is subjected to shear between concentric rings, which are removable, so that sets of rings may be prepared for later testing in the one viscometr, and the water in the water bath holds the asphalt in the annulus of hydrostatic pressure, thus eliminating end effects. It is claimed that complete characterization of the deformation behaviour of unknown samples may be obtained by routine tests requiring less total time than the penetration test.

The publication of papers such as the above should be of extreme interest and support to rheologists who have been stressing for a long time the necessity of expressing flow characteristics in absolute units.

W. F. FAIR JR.

(1) The Texas Company, Port Neches, Texas
(2) The Shell Development Company, Emeryville, California

# APPLICATION

Mr. H. R. Lillie, Secretary
Research Division
Corning Glass Works
Corning, N. Y.


I hereby apply for membership in the Society of Rheology for the year ........................................ as follows:

[ ] Sustaining membership (including subscriptions to both **Journal of Applied Physics** and **R. S. I.** $25.00 or more

[ ] Regular membership (including subscription to **Journal of Applied Physics)** $6.00 (foreign, $6.50)

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