RHEOLOGY BULLETIN

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RHEOLOGY BULLETIN

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EDITORIAL

Help Wanted

War is the enemy of science. War demands secrecy, science thrives by publicity. Progress in science requires time for creative thinking, war demands that time for production and destruction. War tends to eliminate all that is not of immediate practical value, science points to the future for its practical justification. War breaks out when reasoning fails, science blossoms forth when reasoning flourishes. Men of science have a heavy responsibility in war-time: as men they must contribute to the war effort as directly as possible, as scientists they must do all in their power to preserve their science.

The Rheology Bulletin was created to help workers in the fields of elasticity, viscosity, plasticity and the like, to a better understanding of their common problems. It was created as a medium for the exchange of information as to theories and methods pertaining to the rheological properties of matter. Glasses and pitches and synthetic resins have many features in common, so do suspensions of clays and of pigments and of cements.

The Rheology Bulletin needs your assistance, you need the Rheology Bulletin. Send some abstracts to the Editor for the next issue so that it can be published on time. Let us "Take arms against a sea of troubles, and by opposing, end them". Let us not lose the Bulletin as a casualty of war. America has a great chance for leadership in the post-war developments of the rheological sciences. Let us keep the way open. Every abstract helps. In the old Scotch wording "many a mickle makes a muckle".

CONFERENCE ON RUBBER ELASTICITY
AT THE POLYTECHNIC INSTITUTE OF BROOKLYN

Two lectures dealing with the present state of the theories on rubber elasticity are scheduled for presentation on April 3, 1943 at 10:30 a.m. at The Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y. The program is sponsored jointly by this Institute and by the Society of Rheology. The speakers are Dr. M. L. Huggins, Research Laboratory, Eastman Kodak Co., Rochester, N. Y., and Dr. W. L. Wood, National Bureau of Standards, Washington, D. C.

Dr. Huggins topic is "Statistical Treatment of Long Chain Molecules". Dr. Wood speaks on "Present Experimental Aspect of Rubber Elasticity".

Special invitations have been extended to a number of well known specialists in the field of rubber and related

polymers, and it is expected that the discussions will be both interesting and profitable. The meeting has been arranged by Professor H. Mark, President of the Society of Rheology.

THE 1943 FALL MEETING

It is expected that the Society of Rheology will be able to hold its Annual Meeting in 1943 as usual. This meeting will probably take place in New York City near the end of October, 1943, as has been the case the past few years.

W. F. Fair, Jr. has been appointed Chairman of the Program Committee, and is anxious to schedule a tentative program somewhat earlier than in previous years, because of the unusual and frequently changing conditions under which all members of the Society are now working.

Individual members of the Society are especially requested to write to W. F. Fair, Jr., Mellon Institute, Pittsburgh, Pa., if they expect to be able to present a paper on Rheology next Fall, or if they can suggest possible contributors for the October Program. These offers or suggestions need not be considered as definite commitments at this time but merely as tentative proposals for discussion subject to later acceptance or withdrawal as necessitated by future circumstances.

The Chairman of the Program Committee is extremely desirous to arrange a well diversified and well balanced program, and would be glad to consider for presentation both theoretical discussions, as well as contributions from research workers in the various industrial or technical applications of rheology, many of which have become of such extreme importance during the past few years.

If members of the Society have any suggestions to offer please communicate with the Chairman of the Program Committee immediately so that steps may be taken early enough to insure the completion of a worthwhile program for the 1943 Meeting.

THE GRADING OF RHEOLOGICAL MATERIALS

Eugene C. Bingham

In Synthesizing rubber, the striking fact stands out that the substance that we are so eager to obtain is not a chemical compound whose formula we can write, but a product having certain rheological properties of elasticity, yield value and tensile strength. This might be disheartening if it meant indefiniteness of our goal. On the other hand, there are many combinations of the above properties which are needed for different purposes, and the infinite variations

of composition, polymerization and compounding hold out
wide promise.

This same indefiniteness of composition required for
quite specific rheological properties is found in other
materials such as in adhesives, lubricants, pitches, paints.
I wish here to discuss the need for an adequate system of
grading, which, I believe, does not exist at present. Let
us assume that the fluidity is the property of a pitch or
glue that is of primary importance in its use. The system
proposed is equally applicable for all ranges of fluidity
from that of a gas $\Phi = 10,000$ rhes to hard glass $\Phi = 10^{-26}$,
viz, 10^{30} fold. From Fechner's well-known law, all scientific
grading should be based upon the principle that the different
sizes should increase by a constant ratio, i.e., in a ge-
ometrical series. This is expressed by the simple law that
if y is the product being graded, the grades or sizes, x,
should conform to the formula

$$\Phi = 10^X$$

which, of course, may be written

$$LOG\ \Phi = X$$

This means that sizes -2, -1, 0, 1, 2 would correspond to
fluidities 0.01, 0.1, 1, 10, 100 rhes, etc.

It is interesting to note that physical chemists al-
ready use such a system for ionic concentrations. They re-
fer to $-x$ as the pH. In grading viscosities the same object
would be accomplished by using the term $(p\Phi)$, the fluidity
Φ being the reciprocal of the viscosity η, and $(p\Phi)$ being
simply the logarithm of the viscosity.

This system would thus yield but thirty integral grades
over the entire range to be covered normally, but as many
fractional sizes could be added as may be necessary, thus
between 0 and 1, there might be the following

Size No.	0	-0.2	-0.4	-0.6	-0.8	-1.0	-1.2	-1.4	-1.6
Fluidity	1	1.6	2.5	4.0	6.3	10.0	16	25	63

The above sizes are in exact arithmetical progression
and they are positive for all fluidities less than unity.
The corresponding fluidities nearly repeat themselves multi-
plied by ten, but they are "rounded off"; these are the so-
called "preferred numbers" of various writers (1) on the
subject of grading and sizing. By using $p\Phi$ values, no
rounding-off is necessary. The $p\Phi$ value at once gives one
the fluidity without difficulty. The system is available
for all types of products. But the same product may of
course be graded also on the basis of other important

properties at the same time. It will be observed that when $p\Phi = 0$, that Φ = one rhe. By the use of a scientific method of grading and sizing it seems possible to avoid hap-hazard and conflicting empirical devices like the various gages for wire.

(1.) Hirshfeld and Berry, Size Standardization by Preferred Numbers, Mechanical Engineering 44, 791 (1922).

THE FLUIDITY OF ELECTROLYTES

Eugene C. Bingham and Robert T. Foley

The viscosity of mixtures of inert liquids was early assumed to be additive, curve $A\eta$, in the figure,

$$\eta = a\eta_1 + b\eta_2 \tag{1}$$

The equation was never regarded as in accordance with the facts, but only slowly has it become clear that not the viscosities but the fluidities must be additive when the concentrations of the components are volume fractions. Even then the equation, curve N , in the figure for the ideal case

$$\Phi = a\Phi_1 + b\Phi_2 \tag{2}$$

shows well-recognized deviations from the observed data due to two main causes. In the one case, as in that of aniline and pyridine, the components appear to unite to form a compound of lower fluidity, curve $C\Phi$, in the second case, typified by potassium chloride dissolved in water and also by non-electrolytes, such as urea, there is apparently a breaking down of the association of the water complexes, resulting in an elevation of the fluidity curve, to $D\Phi$. It appears from the figure, and it may be proved that the conclusions are general [2], that 1) the values on the N_η curve computed from the N_Φ curve are always lower [3] than expected if viscosities were additive, A_η ; 2) that the D_η curve computed from the D_Φ curve is still lower; but 3) that the C_η curve is computed from the C_Φ curve is not so low as the D_η curve. These predictions, however, are less and less important as the fluidities of the components approach equality. Thus any pair of liquids which on mixing gives a linear fluidity curve, N_Φ , should give a viscosity curve, N_η , which is lower than that calculated by equation (1), A_η . Moreover, any pair of liquids which expand on mixing, absorbing heat and exhibiting a fluidity of the D_Φ type, will show the same effect to an even greater degree. Only when there is evidence of chemical reaction between the components, indicated by heat evolution and contraction as well as the C_Φ type of curve, will the position of the viscosity curve be uncertain, sometimes lower than the calculated but sometimes

higher. These peculiarities of behavior afford good but heretofore unused evidence as to the correct additive function.

The authors have tested out their predictions using the data of Ruby and Kawai[3] and of Brückner.[4] In both cases the deviations between the observed and calculated values are reduced by one-half on using the fluidities, and the deviations verify the above predictions. A study of the data enables us to point out a fact which has heretofore escaped notice. When two solutions having a common ion such as hydrochloric acid and potassium chloride or ammonium chloride and potassium chloride are mixed, the observed fluidity is appreciably below the calculated value. The clue to the reason is the fact that when two solutions of any one of the above salts are mixed in equal volume, the fluidity of the mixture is above the expected value. When, therefore, a solution of potassium chloride is mixed with a solution of some other chloride the potassium ion is diluted, tending to increase the fluidity. If, as in the case of hydrochloric acid and ammonium chloride, they each show the same behavior, there will be an increase of fluidity due to the dilution of each. This correction is only noticeable in concentrated solutions, but it amounts to a maximum of one per cent for mixtures of four normal HCl + KCl, 0.8 per cent for HCl + NaCl but is inappreciable for HCl + NaCl. With NH_4Cl + NaCl it rises to a maximum of nearly six per cent. If these conclusions are correct, mixtures of sodium chloride and barium chloride should obey the additive fluidity theory extremely well because solutions of different concentration of both salts on mixing obey the theory, thus for barium chloride at 15° the formula $\Phi = 87.44 - 8.64\ c$, holds where c is the normality, as shown by the following table

Fluidity of $BaCl_2$ solutions at 15°C.

c	Φ obs.	Φ calc.
0.0	87.4	87.4
0.5	83.2	83.1
1.0	78.8	78.8
1.5	74.5	74.5
2.0	70.2	70.2
2.5	65.8	65.8
3.0	61.0	61.5

1. Second comm., cp. J. Phys. Chem. 45, 885 (1941).
2. Fluidity and Plasticity, pp. 88 et seq.
3. The values of the viscosities are calculated from the assumed values for the pure components.
4. Ruby and Kawi, J. Am. Chem. Soc., 48, 1119 (1926).
5. Brückner, H., Wied. Ann. 42, 287 (1891).
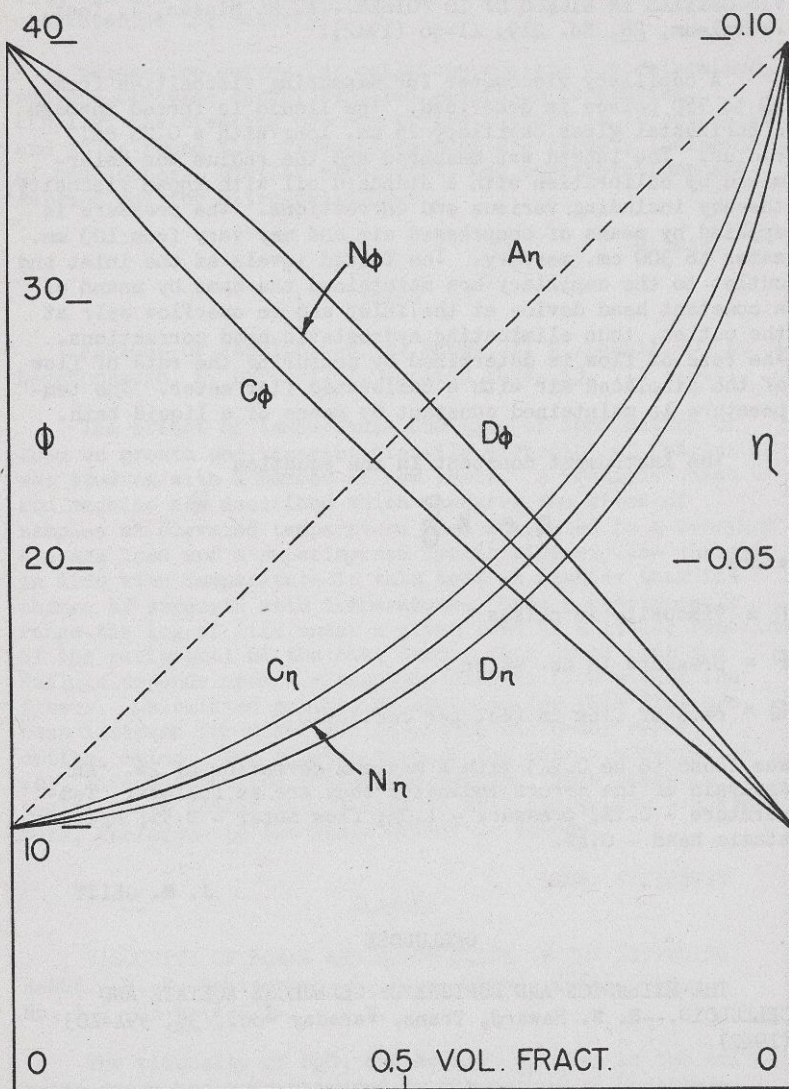
THE DEVELOPMENT OF A CAPILLARY VISCOMETER – TO MEASURE
VISCOSITIES IN EXCESS OF 10 POISES.—A. H. Nissan, J. Inst.
Petroleum, 28, No. 219, 41-56 (1942).

A capillary viscometer for measuring viscosities from
10 to 750 poises is described. The liquid is forced through
a horizontal glass capillary 25 cm. long with a 0.26 cm.
radius. The length was measured and the radius was deter-
mined by calibration with a standard oil with known viscosity,
thereby including various end corrections. The pressure is
applied by means of compressed air and may vary from 100 mm.
water to 300 cm. mercury. The liquid levels at the inlet and
outlet to the capillary are maintained the same by means of
a constant head device at the inlet and an overflow weir at
the outlet, thus eliminating hydrostatic head corrections.
The rate of flow is determined by measuring the rate of flow
of the displaced air with a calibrated flow meter. The tem-
perature is maintained constant by means of a liquid bath.

The instrument constant in the equation

$$\eta = k \frac{P}{Q}$$

where

η = viscosity in poises

P = pressure in mm. water

Q = rate of flow in (cc. per sec.) $\times 10^{-2}$

was found to be 0.745 with a maximum deviation of 2%. An
analysis of the errors indicates they are as follows: Tem-
perature – 0.1%; pressure – 1.0%; flow meter – 0.5%; hydro-
static head – 0.4%.

J. M. GEIST

CELLULOSE

THE EXTENSION AND RUPTURE OF CELLULOSE ACETATE AND
CELLULOID.—R. N. Haward, Trans. Faraday Soc., 38, 394-403
(1942).

Flow curves of cellulose acetate and celluloid are
taken over a wide range of initial stresses and analyzed.
They show that one has elastic and viscous processes super-
imposed to each other. Hookean extension leads to a modulus
of elasticity of about 24,000 kilograms per square cm. In
order to treat the non-Hookean extension conveniently, the
Hookean part is subtracted from the total extension and the
remaining curves are subjected to a mathematical analysis.

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This analysis is carried out with the use of an equation proposed by Nutting, Scott Blair and Coppen. It expresses the elongation as a function of the stress and the time with the aid of three independent numerical constants which characterize the material.

Relaxation curves for cellulose acetate are determined and the behavior during repeated extension is studied. Finally, the breaking process or the rupture is investigated and it is found that flow and rupture are largely independent of each other. Similar experiments and considerations are carried out for nitro-cellulose.

H. MARK

FIBERS

FATIGUE OF FABRICS.—W. F. Busse, E. T. Lessig, D. L. Loughborough, L. Larrick, J. Applied Phys. $\underline{13}$, 715 (1942).

The effect of temperature and time of application of load on growth and apparent "tensile strength" of fabrics was studied with a number of new tests. A "fatigue" test and machine are described which measures the lives of samples at elevated temperature when subjected to a constant average load and a superimposed cyclic stress. The change in life with temperature in this test is greater than the change of strength with temperature. Over a considerable range the log of life under a given load is a linear function of the reciprocal of the abs. temp.; this shows that the failure depends upon a viscous or plastic flow within the fibers. Calculated activation energies for this flow process increase for different fibers in the order rayon, cotton, nylon. The construction of the fabric affects the abs. life but not the activation energy. When creep is negligible a loaded cord contracts with increasing temperature, analogous to the Joule effect in rubber.

CHEM. ABSTRACTS

GLASSES

VISCOSITY OF BORAX AND BORON OXIDE IN THE SOFTENING RANGE.—B. V. Rabinovich, J. Phys. Chem., (USSR), $\underline{16}$, No. 1-2, 23-6 (1942).

The viscosity of B_2O_3 and $Na_2B_4O_7$ glasses in the softening range has been measured by the method of English (J. Soc. Glass Tech., 7, 25, 1923). The result checks fairly well with that of Arndt, Parks and Spaght, and Volarovich and his associates. The experimental data are given in the following table.
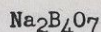
B_2O_3		$Na_2B_4O_7$	
t °C.	η , poises	t °C.	η , poises
222	6.82×10^{13}	452	1.03×10^{12}
240	6.50×10^{12}	476	1.32×10^{10} *
256	1.05×10^{12}	501	2.40×10^{9}
273	2.71×10^{11}	529	7.10×10^{7}
307	9.34×10^{9}	531	5.48×10^{7}
331	9.02×10^{8}	550	7.47×10^{6}
358	7.07×10^{7}		
372	2.23×10^{7}		

* A misprint in the original article.

K. H. SUN

METALS

MECHANISM OF METALLIC FRICTION.--F. P. Bowden and D. Tabor, Nature, 149, 197 (1942).

PLOUGHING AND ADHESION OF SLIDING METALS.--F. P. Bowden, A. J. W. Moore, D. Tabor, J. Applied Phys., 14, 80 (1943).

Studies of the surface damage caused by the sliding of clean metals on one another show that penetration and distortion occur to some depth beneath the surface. Further measurements of the actual areas of contact during sliding by measuring the electrical conductance between the two metals, and of the frictional forces produced under various loads have shown that

1. The area of contact is small and almost independent of apparent area of contact.

2. The deformation of the surfaces in actual contact is mainly plastic.

The first observation offers an explanation of the Coulomb law (frictional forces are independent of the area of sliding bodies), whereas the second observation suggests an explanation of Amantons law (frictional forces are proportional to the applied load).

These and other results have led the authors to a more quantitative theory of metallic friction and it is shown that an approximate calculation of the friction between metal

surfaces may be made in terms of known physical properties
of the metals.

ROLF BUCHDAHL

THE HARDNESS OF PRIMARY SOLID SOLUTIONS WITH SPECIAL
REFERENCE TO ALLOYS OF SILVER.—John H. Frye, Jr. and
William Hume-Rothery, Proc. Roy. Soc. A, 181, 1-14 (1942).

Accurate Meyer analyses have been made on annealed
bars of vacuum-melted spectroscopically pure silver, assay
silver, and on binary alloys of silver containing up to 5
atomic % of cadmium, indium, tin, antimony, zinc, aluminum,
magnesium, and gold. The results show that in contradiction
to the statements of some investigators, the ultimate Meyer
hardness P_u increases as the grain size of the specimen
diminishes. By means of suitable annealing treatments re-
sults were obtained for different grain sizes of alloys con-
taining approximately 2.4 and 5.0 atomic % of the above
elements, and these were used to deduce P_u values referring
to one standard grain size. These values enable an accurate
comparison of the relative hardening effects of the different
solutes to be made. The results are discussed from the
standpoint of lattice distortion, and it is shown that for
a given atomic percentage of solute, the increase in P_u is
proportional to the square of the lattice distortion for
solutes in the same row of the Periodic Table. No simple
relation exists for solutes from different rows of the Peri-
odic Table, and for a given solute the relation between P_u
and the composition is not necessarily a simple one. The
conclusions are tested by experiments on ternary alloys, and
data for copper alloys are discussed.

Proc. Roy. Soc. Abstract
J. R. LOW, JR.

A STRESS-STRAIN CURVE FOR THE ATOMIC LATTICE OF MILD
STEEL IN COMPRESSION.—S. L. Smith and W. A. Wood, Proc.
Roy. Soc. A, 181, 72-83 (1942).

A stress-strain curve has been obtained for the atomic
lattice of mild steel subjected to compression. A set of
atomic planes is selected for which the spacing is practically
perpendicular to the direction of the stress, and the change
in spacing is measured as the magnitude of the applied stress
is systematically varied. The behaviour of the lattice is
compared with the corresponding stress-strain relation for
the external dimensions in the compression test, and also with
the lattice stress-strain curve previously obtained for the
same material when subjected to tensile stress. Other experi-
ments are described on the behaviour of the lattice of pure
iron in compression. It had been previously shown that at the
external yield in tension the atomic spacing exhibited an

abrupt change which remained indefinitely on removal of the
stress; the effect was interpreted as a lattice yield point.
The present work establishes that the lattice possesses a
yield point also in compression, again marking the onset of
a permanent lattice strain. The direction of this strain,
however, is opposite to that found in tension, and the mag-
nitude increases systematically with the applied stress. The
experiments on the pure iron show that under extreme defor-
mation the permanent lattice strain tends to a limit and that
with continued deformation partial recovery from the strain
may occur. The results suggest that the mechanics of the
metallic lattice involve the principle that, after the lattice
yield point, in a given direction the lattice systematically
assumes a permanent strain in such a sense as to oppose the
elastic strain induced by the applied stress.

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Proc. Roy. Soc. Abstract
J. R. LOW, JR.

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ON DISLOCATION THEORY AND THE PHYSICAL CHANGES PRODUCED
BY PLASTIC DEFORMATION.—J. S. Koehler, Amer. J. Phys., 10,
275 (1942).

Quantum mechanical calculations of elastic constants of
solids, based on displacement of atoms in crystals assumed
to be in a perfect periodic lattice, allow Hooke's law to be
valid up to 10^{10} dynes/cm.^{2} of stress. Since actual tests
show that Hooke's law may not hold above 10^7 dynes/cm.^{2} stress,
it is thought that some kind of crystalline imperfection
exists allowing plastic deformation at lower stresses than
necessary theoretically. The theory of dislocations using the
Prandtl model is the most promising explanation of this dis-
crepancy from theory.

The changes in the following physical properties are
linked with change in the density of dislocation: Hardness,
energy stored, magnetic properties, density and elastic con-
stants, and electric resistance.

Work hardening is the result of a large number of inter-
nally trapped dislocations. Work hardening produces a con-
dition whereby energy is stored in the crystal due to dislo-
cation. Face centered cubic and body centered cubic metals
(Al, Cu, Fe, Ni, Brass) reach a saturation of stored energy.
Metals with hexagonal crystals (zinc, cadmium, and tin) do
not have stress-strain curves that approach constant values
and may not reach a saturation of stored energy.

Cold working decreases the maximum permeability and
increases hysteresis in weak magnetic fields for ferromag-
netic metals. This is explained by the dislocation theory.
Density and elasticity are both decreased by cold working. A
slight dilatation of the solid is given as an explanation of

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density change as well as elastic constant change.

The electric resistance of a metal increases when the metal is cold-worked. Deviations of the crystal from perfect periodicity are known to produce electric resistivity and since cold working increases these deviations, the resistivity ought to be raised. However, calculated and experimental values of change in resistivity are widely different and it is thought that the increased dislocations are not entirely responsible for the increased resistivity.

W.W. PENDLETON

SUSPENSIONS AND PASTES

STRUCTURAL VISCOSITY STUDIES OF COATING CLAY COMPOSITIONS.—G. H. Sheets, Paper Trade J., 116, No. 3, 28 (1943).

The flow properties of various clay dispersions - used as coating compositions for paper - have been studied with a Stormer-type viscosimeter. The author finds that most of the materials show non-Newtonian flow and thixotropic build-up. The amount of dispersing agent is the most important single variable effecting the flow properties of the clay suspensions studied. Other factors influencing the flow properties are the particle size distribution of the clay, the type of clay used and the hydrating ability of the clay.

ROLF BUCHDAHL

SPECIFIC VISCOSITY OF SUSPENSIONS AND SOLUTIONS.— E. W. J. Mardles, Trans. Faraday Soc. 38, 47-54 (1942).

The author determined the ratio of the viscosity of solution or a suspension having a certain concentration, and the viscosity of the pure solvent. This ratio (usually called the relative viscosity of the system) was found to be a function of the viscosity of the pure liquid medium. This empirical fact holds for various suspensions and solutions and is particularly noticeable if the viscosity of the pure solvent is in the neighborhood of or below 2 centipoises. In order to change the value of the viscosity of the liquid, three methods were used.

The first was to apply liquids belonging to a homologous series and exhibiting different viscosities. The other was to work with binary mixtures in which the viscosity could be varied over a comparatively wide range. The third consisted of working at different temperatures. In all cases it was found that the relative viscosity of the given substance at the given concentration increased with the viscosity of the solvent. The proposed explanation is that the dispersed or dissolved particles are oriented by the shearing

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forces in the viscometer and assume their orientation easier
in a thinner liquid than in a thicker one.

<div align="right">H. MARK</div>

INFLUENCE OF SHAKING UPON THE THIXOTROPIC SOL–GEL
TRANSFORMATION.—W. Heller and H. L. Roeder, Trans.
Faraday Soc. 38, 191-4 (1942).

The authors state the setting times of thixotropic
systems and find that this time changes measurably depend-
ing upon whether one shakes the system for a few minutes or
for a few hours. The amount of this change itself depends
upon the stability of the system.

Thixolabile systems are these in which the setting
time changes even after shaking for a few seconds, while
thixotropic systems do not show any sensitivity in this re-
spect. The time effect is attributed to a mechanical coagu-
lation, the rate of which depends to a large extent upon the
stability of the system. It is pointed out that one has to
take such shaking effects into account whenever setting times
are determined and used as a measure to define the thixo-
tropic state.

<div align="right">H. MARK</div>

INTERPRETATION OF VISCOSITY MEASUREMENT OF STARCH
PASTES.—B. Brimhall and R. M. Hixon, Cereal Chem. 19,
No. 4, 425-441 (1942).

The viscosities of water dispersions of corn starch
at 90° are studied using capillary type viscometers of
varying bore. Below 2% starch concentration, the viscosity
is essentially independent of the rate of shear, but at
higher concentrations, large variations are noted. By

plotting the log of the applied stress $\dfrac{P_g R}{2L}$ vs. the

log of the rate of shear $\dfrac{4V}{\pi R^3 T}$ straight line plots are

obtained for dispersions ranging from less than 2% to 6%
starch. These quantities do not extrapolate to a common
point but obey the relation

<div align="right">(1)</div>

where
P_g	=	applied pressure
R	=	radius of capillary
L	=	length of capillary
V	=	volume of bulb
T	=	time of flow
M	=	slope of log – log relationship
C	=	intercept value.

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For water and a 2% paste $M = 1$. C increases as the viscosity increases. Hence the viscosity of starch pastes of less than 6% concentration may be expressed independently of the viscometer constants, (capillary bore and rate of shear) when $\log \frac{4V}{\pi R^3 T} \leqslant 10000$.

The viscosity η may be calculated from eq. (1) since $\eta = \frac{1}{M}$ at any one point, and

$$LOG\ \eta = LOG\ \frac{P_g R}{2L} - LOG\ \frac{4V}{\pi R^3 T}$$

The volume of the suspended starch was determined by centrifuging cooled starch pastes for 1/2 hour at 1750 r.p.m. (15 cm radius), and straight line functions were found relating concentration in gms. to volume of starch, the slope of the lines being affected by the temperature to which the paste was heated. The relation of Hatschek

$$\eta_r = \frac{1}{1 - \sqrt[3]{\phi}} \qquad (2)$$

where ϕ volume of the spheres was checked from this data, and the ratio of calculated to observed volume raises from 0.5 to 1.8 according to the relative viscosity and temperature at which the pastes were prepared.

The relation of Rash & Alsberg (1924)

$$LOG\ \eta = LOG\ c + mc \qquad (3)$$

where $\quad$ $c =$ concentration of starch
$\quad\quad\quad$ $m =$ slope
was checked, and the rate of shear was found to cause large deviations from the theoretical values.

In measuring the viscosity of aqueous starch pastes, it is recommended that measurements be carried out at 90° to eliminate the effects of gelling, retrogradation that occur in cooling. The viscosities measured in different instruments may be correlated as shown by (1). Large changes in apparent viscosity occur when a suspension is heated at 90°. Viscosity characterizations should be taken on pastes which have reached an equilibrium viscosity.

Viscosity - time relationships should be determined on any paste to determine the minimum heating time which may be safely used.

W. LINDSAY

THEORY

THE KINETICS OF HIGH ELASTICITY IN SYNTHETIC POLY-
MERS.—R. F. Tuckett, Trans. Faraday Soc., 38, 319 (1942).

The total reversible elastic deformation in a polymer
can be considered as the superposition of two components.
The first corresponds to the instantaneous strain produced
in a crystal by the displacement of the constituents of
the lattice relatively to each other. The second part,
the highly elastic deformation, is strongly temperature de-
pendent and approaches its equilibrium value asymptotically.
The rate of this process is determined by the free energy
of activation necessary for the reorientation of the long
chains upon application of stress. Its magnitude in turn
measures the temperature range above which highly elastic
behavior is practically completely developed. It is point-
ed out that this transition range contains also the tem-
peratures at which a second order transition occurs in re-
spect to the expansion coefficient

$$\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_n$$

of the polymer. This indicates that both types of phenome-
na are related to each other. The author suggests that this
transition marks the setting in or the disappearance re-
spectively of relatively free rotation around C-C bonds
along the chain and discusses on this basis the elastic pro-
perties of various rubbers and vinyl derivatives and the
effects of plasticizer and introduction of cross links.

Generally speaking, the position of the transition
point is determined by the mean relaxation time derived from
the whole distribution existing in high polymers. It will
therefore depend mainly upon the contribution of the segment
motions to the relaxation spectrum. These in turn will cer-
tainly be influenced by the degree of free rotation. The
reviewer shares, however, the opinion discussed recently in
the literature at various occasions, that this factor alone
does not cause the differences between different high polymers.

A longer discussion follows this interesting paper pre-
sented in the course of a symposium on the Structure and Re-
actions of Rubber.

ROBERT SIMHA

THERMODYNAMIC STUDY OF THE ELASTIC EXTENSION OF RUBBER.—
L. R. G. Treloar, Trans. Faraday Soc., 38, 293 (1942).

Thermo-elastic data of various authors are discussed
and evaluated to give the isothermal change of internal
energy and entropy or stretching. This can be done on the

basis of stress-temperature data or by measurement of the heat absorbed. Both types of data, available only to a limited extent, confirm the fundamental assumption of the kinetic theory of rubber-like elasticity. For extensions not exceeding a few hundred percent, when crystallization is not very appreciable, the change of free energy on stretching is mainly an entropy change, and it is justified to treat the variation of the internal energy upon stretching as a small correction.

<div align="right">ROBERT SIMHA</div>

INTERSTITIAL FLOW.—R. T. Hancock, Mining Mag., <u>67</u>, 179-86 (1942).

The general problem of the flow of liquid or gas among solid particles in suspension or active movement, and also among stationary solid particles as in beds is discussed. This type of analysis has an application to such systems as the flow of water and oil towards wells and springs, the emission of gas from coal faces, the combustion of fuel, suspensions, filtration, mineral separation, earth dams, hydroulic conveyance of solids, dust collection, and scrubbers.

Hancock's work consists primarily in the adaptation of the mathematics of freely falling spheres in a liquid medium to the more complicated problem of multi-particle systems having mutual interference in the hydraulic system. To do this, he considers the "voidage" in the system and introduces this quantity into the fundamental equation for a freely fall sphere. Hancock shows that the voidage, which is the ratio of space unoccupied by the solid to the total volume occupied by both solid and liquid, when properly introduced into these equations enables one to check the flow data very closely; and since the voidage is a dimensionless quantity, the resulting equations are still dimensionally correct. The manner in which the voidage is introduced into the fundamental equation for the velocity of flow is determined by cut and try methods until a close fit of the calculated values to the observed data is obtained, and Hancock find the voidage is a sixth power function in the case of suspensions and a fourth power function in the case of immobilized beds.

The following equations result from this analysis:

Freely Falling Sphere –

$$\Psi = \frac{4}{3} \cdot \frac{(s-\rho)}{\rho} \cdot \frac{g\,d}{v^2}$$

Velocity of Flow for a Fluid and Solid Suspension –

$$v^3 = \frac{4}{3} \cdot \frac{g\eta(S-\rho)}{\rho^2} \cdot \frac{R(1-\lambda)^6}{\psi}$$

Velocity of Flow for a Fluid through an Immobiliz-
ed Bed –

$$v^3 = \frac{4}{3} \cdot \frac{g\eta(S-\rho)}{\rho^2} \cdot \frac{R\ (1-\lambda)^4}{\psi}$$

where

g = acceleration of gravity, cm/sec. ^{2}.

η = viscosity of fluid, gm/sec.–cm.

ρ = mass density of fluid, gm/cm^3.

S = mass density of solid; gm/cm^3.

d = diameter of solid particles, cm.

v = velocity of fall or flow.

λ = ratio of solid to total volume, dimension-
less.

$(1-\lambda)$ = ratio of fluid to total volume, dimension-
less.

R = Reynold's number, dimensionless.

ψ = Resistance coefficient, dimensionless.

The derivations of these and other equations are dis-
cussed, and also the work of other authors. Bibliography.

L. E. WELCH

LETTER TO THE EDITOR

Sir: I noted with considerable interest Mr. Nason's
letter published in the Rheology Bulletin Vol. XIII No. 4 con-
cerning the advisability of adopting a standard system of
notation for the presentation of the mathematical theory of
Rheology. I agree with Mr. Nason that a Universal and Inter-
national system of notation would be a very worthwhile accom-
plishment, but I doubt if such a project is at all feasible.
My contention is borne out by the failure of other Profession-
al Societies to accomplish this feat.

However, perhaps a more pertinent suggestion would be
that we adopt a standard system of symbolic notation to be
used exclusively by all who participate in the activities of
the Society of Rheology. This was suggested previously by
Markus Reiner, Rheology Bulletin, Vol. 3 No. 2, April 1932,

but nothing ever came of his efforts. There are many
physical quantities which are and will be used very fre-
quently in the discussion of rheological phenomena, and there-
fore we should adopt a standard system of notation for these
quantities. In the light of this, I have made up a tentative
list of these common physical quantities together with my
suggestions as to how they should be characterized symbolic-
ally. It seems to me that rheology is very closely akin to
the well founded theory of mechanics, and therefore our
standard symbols should duplicate as nearly as possible those
used in the presentation of the theory of the mechanics of
solid bodies. The readers' comments will be appreciated.

Very truly yours,

L. E. WELCH,

BAKELITE CORPORATION.

A TENTATIVE SYSTEM OF SYMBOLIC NOTATION FOR THE RHEOLOGY SOCIETY

m	Mass
ρ	Mass density
W	Weight
P	Force (Applied)
σ	Normal stress (Tension and Compression)
τ	Shear stress
p	Pressure
ε	Normal strain (Tension and Compression)
γ	Shear strain
$\dot{\varepsilon} = \dfrac{d\varepsilon}{dt}$	Rate of normal strain
$\dot{\gamma} = \dfrac{d\gamma}{dt}$	Rate of shear strain
g	Acceleration of gravity
a	Linear acceleration
α	Angular acceleration
v	Linear velocity
ω	Angular velocity
t	Time
e	Base of Napierian or Natural Logarithms
E	Tension and Compression Modulus of Elasticity
G	Shear Modulus of Elasticity
M	Molecular Weight
	Viscosity
$\phi = \dfrac{1}{\eta}$	Fluidity
Q	Efflux or discharge rate
V	Volume

a, b, l, L, r	Dimensions
A, B, C, D, K	Constants
m, n, p, q	Subscripts or exponents
R	Universal gas constant
N	Number
f	Frequency
c	Velocity of sound
σ_0	Tension and compression yield stress
τ_0	Yield stress in shear
T	Temperature
T_A	Absolute Temperature

APPLICATION

R. B. DOW, Secretary-Treasurer
  Ballistics Research Laboratory
  Aberdeen Proving Ground, Maryland.

I hereby apply for membership in the Society of Rheology commencing January 1 .... as follows:

Sustaining membership (including subscription to Rheology Bulletin, Journal of Applied Physics, and Review of Scientific Instruments.) $25.00 or more.

Subscribing membership, (including subscription to Rheology Bulletin and Journal of Applied Physics.)
                                          $7.00 (foreign, $7.70)

Membership, (including subscription to Rheology Bulletin.) $2.00

Please also enter my subscription for the following additional periodicals published by the American Institute of Physics, at the rates available to members of the five founder societies:

Review of Modern Physics ....$3.00 (foreign, $3.40)
Review of Scientific Instruments,......$3.00 (foreign, $3.50)
Journal of Chemical Physics..........$10.00 (foreign, $11.00)

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