

RHEOLOGY BULLETIN

Publication of the Society of Rheology

Volume 32, No. 1

Spring, 1963

THE FOURTH INTERNATIONAL CONGRESS ON RHEOLOGY

This year's Annual Meeting will be combined with the Fourth International Congress on Rheology which will be held at Brown University, Providence 12, Rhode Island, from August 26 to August 31, 1963. It is planned to award the Bingham Medal at the Congress, and the business meeting of the Society will be held during the Congress. The Congress will be held under the auspices of the International Committee on Rheology and under the Honorary Presidency of Professor F. H. Müller of Marburg/Lahn. The Society of Rheology will act as the host organization. Dr. Robert S. Marvin, National Bureau of Standards, and Professor R. S. Rivlin, Brown University are Co-chairmen of the Congress, and Professor E. H. Lee, Stanford University is the Editor.

All aspects of rheology are within the scope of the Congress. In view of the growing interest in the subject, a special Symposium on Biorheology under the Chairmanship of Professor A. L. Copley, New York Medical School, will form part of the scientific program of the Congress.

An interesting program of general lectures and invited papers has been arranged. In addition all participants in the Congress are invited to contribute papers. Twenty minutes will be allotted for presentation of each contributed paper and ten minutes for discussion. Those wishing to contribute papers should send abstracts of approximately 500 words to the Editor, E. H. Lee, Stanford University, Stanford, California to reach him by April 30, 1963. Papers presented at the Congress will be published in the Proceedings of the Congress, subject to the wishes of the authors and to refereeing. These Proceedings will include this year's issue of the Society's Transactions which will probably comprise more than one volume. Arrangements will be made to provide members with their usual Transactions volume, details depending on the eventual form of the Congress Proceedings.

Contributors who wish their papers to be published in the Proceedings of the Congress should submit a typescript no longer than 6000 words to the Editor, Professor E. H. Lee, before the end of the Congress on August 30, 1963. Papers which are not received by this date will be published in abstract only. Typescripts of papers which contain diagrams or tables should be correspondingly shorter than 6000 words.

There will be a registration fee of \$15.00 which will

entitle the registrant to attend the scientific sessions of the Congress and to participate in the social functions, without extra charge. It will also entitle the registrant to receive a copy of the published Proceedings of the Congress. No registration fee will be charged for spouses or children of participants.

Accommodations for participants and their families will be available in the dormitories of Brown University and in the Sheraton-Biltmore Hotel in Providence.

Further details of the local arrangements, and application blanks are available by writing to Professor Rivlin, Division of Applied Mathematics, Brown University, Providence 12, Rhode Island.

COMMITTEE APPOINTMENTS

The President has appointed the following committee chairmen and committees:

Bingham Award

H. LEADERMAN (Chairman)
T. A. LITOVITZ
R. S. RIVLIN
R. SIMHA
T. L. SMITH

Nominating Committee

R. F. LANDEL (Chairman)
J. H. ELLIOTT
I. L. HOPKINS

Membership Committee

A. F. LEWIS (Chairman)
E. B. BAGLEY
P. S. FRANCIS

NOMINATION OF OFFICERS FOR 1964-65

The following nominees have been recommended by the Nominating Committee; in accordance with our constitution, ballot forms will be sent out later in the year.

President

J. T. BERGEN, Physical Research Center, Armstrong Cork Company, Lancaster, Pennsylvania.

Vice President

R. S. MARVIN, National Bureau of Standards, Rheology Section, Washington 25, D.C.

Secretary-Treasurer

J. C. MILLER, Union Carbide Plastics Company, Bound Brook, New Jersey.

RHEOLOGY BULLETIN

E. H. Lee, Editor

Division of Engineering Mechanics
Stanford University
Stanford, California

Editor

R. R. MYERS, Lehigh University, Bethlehem, Pennsylvania.

Executive Committee

E. A. COLLINS, B. F. Goodrich Chemical Company, Avon Lake Experimental Station, P.O. Box 122, Avon Lake, Ohio.

E. H. LEE, Division of Engineering Mechanics, Stanford University, Stanford, California.

H. MARKOVITZ, Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

T. L. SMITH, Stanford Research Institute, Menlo Park, California.

WEST COAST REGIONAL MEETING

The West Coast Regional Meeting was held on January 31–February 1, 1963 at the Shell Development Company, Emeryville, California. The program was arranged by Paul J. Blatz of Cal. Tech., and Thor L. Smith of the Stanford Research Institute. Extremely pleasant meeting facilities were arranged by Dale Meier of the Shell Development Company.

Abstracts of the papers presented are printed below.

INVITED LECTURE. "Optical Properties of Polymers," RICHARD S. STEIN, Polymer Research Institute, University of Massachusetts, Amherst, Mass.

The deformation of crystalline polymers is associated with the orientation of the crystalline and amorphous regions. For slow deformation, this may be followed by x-ray diffraction pole figure analysis and by birefringence measurements. The birefringence principally arises from the crystallite orientation but partly from the orientation of the amorphous regions. The crystal orientation is believed to be a two-stage process, the first of which is an elastic deformation of the spherulite. This is accompanied by an internal reorientation of crystals. The degree to which this occurs is dependent upon the degree of crystallinity, crystal size and perfection, and temperature, and determines the type of crystal orientation which results as well as the mechanical response. The internal rearrangement is time dependent. Consequently, crystal orientation and birefringence are time dependent and these may be studied by such techniques as dynamic birefringence and dynamic light scattering in which the optical response is continuously measured during a time dependent strain. The light scattering technique also indicates that the crystals do not orient

as isolated units but in a motion which is correlated with their neighbors. Such correlation is a consequence of the connectivity between the crystals.

"The Effect of Moisture on Mechanical Properties of Highly Filled Elastomers," A. E. OBERTH and R. S. BRUENNER, Aerojet-General Corporation, Sacramento, California.

Elastomers filled up to 70 volume per cent with inorganic fillers have obtained importance in recent years. For many applications these materials have to maintain a high degree of elasticity; often over a considerable temperature range. It is briefly shown that sufficient elasticity can only be obtained if there is sufficient interaction (bonding) between binder and filler. The primary effect of moisture is the breakage of this binder-filler bond resulting in lower tensile strength as well as lower recoverable elongation. A number of different fillers have been tested showing a rough correlation between the magnitude of the effect and the hygroscopicity of the filler material. Photomicrographs illustrating the dewetting of the binder from the filler are presented. Further evidence is presented with dilatation measurements of wet and dry specimens. Where the filler is bonded by a primary chemical bond, which is not affected by moisture, no change in physical properties is observed.

Recently, a new effect of moisture occurring at low temperatures has been discovered. Many binder systems, when filled with metal perchlorates, show a strong increase in modulus and a significant reduction in elongation. A hypothesis is presented, which relates this "moisture embrittlement" to the dissolution of metal perchlorate in the binder phase by the aid of water. The association of the binder molecules brought about by Coulomb attraction of the ionic species is believed to be responsible for the embrittlement. Experimental evidence supporting this hypothesis is presented.

"Properties of the Liquid State, I: A New Semi-Empirical Equation for Viscosity," P. H. GROSS and H. K. ZIMMERMAN, University of the Pacific, Stockton, California.

The well-known "domain" model of the liquid state is extended, making use of the concept of two classes of molecules, "activated" and "inactive." An argument is presented which shows that inactive molecules must aggregate into a maximum number of domains whose size may be expressed in terms of the number of molecules they contain, while the activated molecules constitute monomolecular layers between such domains. A mathematical expression is derived to give the inactive domain size in terms of temperature and the threshold energy for activation, which may be termed the "activation energy for the liquid state." It is shown that the viscosity of a liquid can be expressed as a simple function of the inactive domain size, and the equation for this function is derived. Combination of these two expressions then leads to an equation for the temperature dependence of viscosity which requires only two empirical constants to express the viscosity of any liquid accurately over the entire liquid range.

"Properties of the Liquid State, II: Calculations of Viscosities over the Entire Liquid Range," P. H. GROSS and H. K. ZIMMERMAN, University of the Pacific, Stockton, California.

A slightly simplified form of the viscosity relation derived in the first paper is used to calculate viscosities of hydrocarbons, associated liquids, and highly viscous liquids over their entire liquid ranges. Among the hydrocarbons, maximum errors near the freezing and boiling points do not exceed two to five percent, while for the associated and very viscous liquids they do not exceed ten percent in most cases. The mean errors are in the range of one percent or less for hydrocarbons and of five percent or less for the other types. Use of the full equation reduces the errors to much lower levels for all classes of liquids tested. The activation energies for the liquid state have been determined for 87 hydrocarbons which are members of five homologous series. These energies are a regular function of molecular structure within each series and follow a curve of the form of the Morse function. This relationship is briefly considered in terms of the sizes of the respective inactive domains.

INVITED LECTURE. *"Viscosity of Non-Associating Liquids,"* A. BONDI, Shell Development Company, Emeryville, California.

Following a short review of difficulties inherent in the activated state treatment of viscosity, the present formulations of molecular theory of viscosity are examined. Guided by the insights of molecular theory, a semi-empirical scheme is developed which permits the representation of viscosity-temperature-pressure functions within the framework of a corresponding states type correlation. To a first approximation only the molecular properties: van der Waals dimensions, the number of external degrees of freedom per molecule, and the standard energy of vaporization, are needed to correlate the viscosity for the two groups of compounds. The liquids composed of rigid molecules are handled in one correlation and the liquids composed of flexible molecules in another.

While most of the work to date has been with hydrocarbons, a few results with the very polar cyano and nitro compounds suggest that they ought to be easily integrated into the proposed correlation scheme. A few examples are also given for the workings of a viscosity-pressure-temperature correlation in the new reduced coordinates.

"The Rheology of Clay Soils," W. J. THOMPSON, Civil Engineering Department, University of California, Berkeley, California.

The soil mechanics study of clay soils is concerned principally with practical engineering application, and the constituent experimentation and analysis involves many necessary (and several unnecessary) significant, simplifying assumptions, particularly with regard to the soil resistance to shear failure. Testing is conducted principally with the triaxial and consolidometer apparatuses. Rheological studies have been principally concerned with shear behavior. Studies by Bingham, Blair,

Gueze and Tan and Haefeli, have indicated the existence of yield behavior and, at higher stresses, a pronounced tendency for the development of structural disintegration, the latter being also observed in conventional triaxial tests. However, it is considered by several workers that the apparent yield behavior is due to experimental inaccuracies, and that the flow curve is of the thinning thixotropic form observed by Ostwald.

Experimental evidence appears to confirm the conclusion of Reiner that volume deformation must be considered as a combination of elastic, viscous, and plastic processes. The rate of expulsion of the pore water occurring with volume decrease in saturated clay soils may be satisfactorily predicted on the basis of Darcy's Law. Recent theoretical studies of clay soil deformation, notably those of Biot and Tan, have been generally based on the assumption of linear viscoelastic behavior. Consideration of the anisotropic and non-uniform structural deformation characteristics greatly complicates the rigorous analysis.

"Serum Viscosity in Rheumatic Diseases," M. A. SHEARN, W. V. EPSTEIN, E. P. ENGLEMAN, and W. F. TAYLOR, Kaiser Foundation Hospitals, Oakland, California.

Microcirculatory derangements have been implicated in the pathogenesis of rheumatoid arthritis. Because changes in viscosity alter blood flow, an investigation was undertaken of serum viscosity in patients with rheumatic disorders. The sera of 100 patients with various rheumatic disorders was compared with that of normal controls. The following tests were performed: F II hemagglutination test for rheumatoid factor, serum viscosity using a Zeitfuchs viscometer with constant temperature control, paper electrophoresis of proteins with quantitation by Spinco Analytrol reader, total serum proteins by biuret reaction. In the majority of patients with rheumatoid arthritis, the serum viscosity was significantly higher than that of normal subjects.

The serum viscosity in other connective tissue disorders was also higher than normal. The increases in serum viscosity were highly correlated with the concentration of gamma globulin (molecular weight = 150,000) and also with rheumatoid factor (molecular weight 10⁶). No significant correlation was found between viscosity and the concentration of alpha-1, alpha-2, beta globulin, or albumin. The alterations in serum viscosity in rheumatoid arthritis and allied diseases are related to rheumatoid factor and increased concentrations of gamma globulin which are frequently found in these disorders. Alterations in the serum viscosity in other disease states will also be presented.

"Rheology of Concentrated Suspensions," E. B. CHRISTIANSEN, A. D. BAER, and JOHN S. CHONG,* University of Utah.

A new sharp-edge orifice viscometer has been designed. The Navier-Stokes equation was applied to obtain a mathematical description of creeping motion

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of viscous fluids and the predicted behavior has been confirmed. The viscometer was used to investigate some flow characteristics of mono-dispersed and bimodal suspensions containing up to 80% solids. Some of the viscosity equations proposed by other people to describe behavior in the high concentration ranges have been tested.

INVITED LECTURE. "Morphological Interpretations of Dynamic Mechanical Properties of Polyethylene," S. MATSUOKA and C. J. ALOISIO, Bell Telephone Laboratories, Murray Hill, New Jersey.

Recent advances in studies of morphology of semi-crystalline polymers accentuate the inadequacy of the familiar fringe-micelle concept. It is now commonly recognized that polymers typically crystallize in a spherulitic form, having a skeletal structure of coherent crystalline lamellae extending radially from the center. The process of crystallization can be divided into three stages: (1) the nucleation and (2) growth of spherulites in the form of growing crystalline lamellae, and finally (3) the further crystallization of the melt in the intervening regions between the lamellae.

Dynamic mechanical behavior of polyethylene is interpreted on the basis of the above morphological findings. A dynamic test apparatus designed by B. Maxwell (ASTM Bull. No. 215, pp. 76-80, July, 1956) was used to study the properties of a branched polyethylene, a commercial linear polyethylene with and without annealing (at 125° C for 3 days), and a linear polyethylene with an extremely high molecular weight ($>10^6$), over a frequency range of 10^{-2} to 10^2 cps, and a temperature range of -70° C to 120° C. Within the temperature range where the degree of crystallinity remains practically unchanged, the temperature dependence of the shift factors for reduced variables for all linear polyethylenes is of the Arrhenius type with an apparent activation energy of 43 kcal/mole. Relations between the loss moduli at 1 cps and the temperature reveal two loss maxima, a so-called beta peak for all samples at -35° C, and also an alpha peak occurring somewhere between 10° C and 80° C depending on the material. (The third peak or the gamma peak occurring at -120° C is well below the range of our experiments.) The temperature for the "alpha" transition increases with the increasing degree of crystallinity. The thermal expansion coefficient of the crystalline unit cell was found to change in the temperature range where this transition occurs in each sample. We propose that motions within the lamellar structure are involved in this high temperature transition. On the other hand, the magnitude of the loss peak at -35° C increases with an increase in the amorphous fractions for all samples except the very high molecular weight linear polyethylene. It is particularly significant that the unannealed linear polyethylene exhibited a pronounced peak while the annealed but otherwise identical sample showed only a trace of it. All maxima for this transition occurred at the same temperature. We propose that this transition involves motions of non-crystalline regions coupled with crystalline lamellae. The very high molecular weight linear polyethylene

deviates at least in some respects from the above generalizations. The unusual behavior of this material is discussed on the basis of its unique crystallization behavior.

"Free Vibration Testing of Highly Filled Polymers in Flexure and Torsion," G. J. KOSTYRKO and W. T. MILLOWAY, Aerojet-General Corporation, Sacramento, California.

Free vibration tests on highly filled polyurethane materials have been made to determine the dependence between dynamic modulus and frequency. A free vibrating reed test was used to determine the complex Young's modulus. A thin constant cross section ($\frac{1}{4}$ " \times 1") varying length piece of filled polymeric material was used for test specimens. Specimens are end bonded on one end and free on the other. They are attached vertically to the deflection sensing element (steel bar with strain gages on it). The free end of the reed is deflected quickly, released and allowed to oscillate until the vibration subsides. The output of the strain gages vs. time is recorded on an oscillograph. From this frequency of vibration an exponential decay or damping is computed. A fourth order partial differential equation is solved for the case of exponentially damped sinusoidal vibration, and yields two algebraic equations for determination of E' and E'' (real and imaginary components of Young's modulus). Thus by changing the reed length, different frequencies of vibration are obtained (2 to 40 cps). The test is performed at several temperatures and the data is shifted to 77° F by means of the WLF equation. It appears the WLF equation is applicable. A torsion pendulum test is used to determine complex shear modulus of real and imaginary components G' and G'' . In this test, one end of the sample is clamped and the other bonded to an inertial disc. The angular rotation of the inertial disc vs. time is measured by means of a Rotary Variable Differential Transformer. Frequency and damping are computed in the same manner as in the reed test. Frequencies are changed by varying specimen cross section and moment of inertia of disc. A second order partial differential equation was derived introducing the linear stress strain operators $P(\sigma)$ and $Q(\epsilon)$ and solved for the eigenvalue with the particular set of boundary conditions. Similar to the vibrating reed analysis, it does not utilize a model representation for obtaining components of complex modulus. Data are presented as modulus vs. frequency at various temperatures for a frequency range of .2 to 5 cps. Both tests yield components of complex modulus as a function of $(i\omega - \lambda)$ rather than a function of $i\omega$.

"A Modified Cole Distribution Function," P. J. BLATZ, California Institute of Technology, Pasadena, California

A new distribution function is proposed which is useful for representing spectra obtained from creep and relaxation data. It has the property that both spectra are Stieltjes transforms of the data and are easily interrelated. Application to Tobolsky's stress relaxation data on polymethylmethacrylate is discussed.

"Thermo-viscoelastic Stresses in a Sphere with an Ablating Cavity," T. G. ROGERS and E. H. LEE, Division of Engineering Mechanics, Stanford University, Stanford, California

The theory for the determination of thermo-viscoelastic stress distributions is presented for radially symmetrical temperature and stress fields in a spherical body. Linear viscoelasticity is assumed in shear with an arbitrary relaxation function, and temperature influence includes thermal expansion and a shift, as an arbitrary function of temperature, of the relaxation modulus on a log-time base according to the Williams-Landel-Ferry law. Elastic response in dilatation is assumed. The examples computed are for polymethylmethacrylate for which the measured relaxation modulus in shear and shift function are available from the literature. The theory determines the varying stress distribution as the solution of an integral equation, or system of integral equations, which can be conveniently solved by finite sum numerical integration using a high speed computer.

The particular problem is solved of an unloaded sphere initially at uniform temperature, with an ablating spherical cavity subjected to a constant higher temperature. The solution shows compressive circumferential stresses immediately ahead of the ablating boundary, with the position of highest stress separated from the boundary by a region in which accelerated relaxation at the higher temperature has caused stress reduction. It has sometimes been suggested that, due to lack of time for sufficient heat to be conducted ahead of the boundary, thermal stress magnitudes will be smaller at higher rates of ablation. The solution demonstrates that in fact the thermal stress magnitude increases and that a narrow boundary layer of intense thermal stress will arise. Slower motion will permit relaxation and hence a reduction in stress magnitudes. The solution is contrasted with that for an elastic body, in which appreciably higher thermal stresses are generated.

"Viscoelastic Analysis of a Cracked Reinforced Concrete Beam," J. L. SACKMAN and R. E. NICKELL, Department of Civil Engineering, University of California, Berkeley

The effect of stress relaxation on a cracked reinforced concrete beam subjected to flexural loading, and the consequent increase of strain and deflection is investigated under the standard assumptions that the strain distribution through the beam depth is linear, the concrete supports only compressive stress and superposition is valid for the compressive region of the concrete. Stress transfer from the concrete to the reinforcement and the corresponding movement of the beam neutral axis as functions of time are also examined.

The impulse formulation of the superposition integral equation for stress, using as the kernel function the response of the concrete to a unit strain input, is utilized in the solution of the problem. For a time-variable material such as concrete the unit strain response is a function not only of time after loading, but also of the curing age. Due to the lack of direct experimental data available on stress relaxation functions for concrete, a numerical inversion technique, using the superposition integral equation, converts the more readily available

creep function into relaxation data. Results for several numerical examples, using typical design parameters and a variable age of loading, are illustrated. The solution to the governing system of coupled nonlinear integral equations is obtained numerically by an iterative forward integration method carried out on a large digital computer.

"Application of the Moiré Method for the Determination of Strain in Filled Viscoelastic Materials," W. D. HART, Aerojet-General Corporation, Azusa, California

The moiré effect is an optical phenomenon produced when two somewhat similar grid systems (master grid and model grid) are superimposed, resulting in the formation of alternating light and dark fringes. Since the fringes are the result of a displacement of one grid with respect to the other, they have been used as a tool for making strain measurements on metals and rigid plastics.

Special methods are described for preparing grids on viscoelastic materials containing fillers, from photographic reproductions on film. The model grids were prepared on the samples by: (1) silk screen process; and (2) a diazo-type photo-sensitive coating. The utility of the method for measuring strains has been further increased by developing methods to produce moiré fringes on a sample surface without actual physical contact of the two grid systems. One method utilizes a projection technique for imposing the master grids on the model grid, while a second method provides superposition by placing a master grid in the focal plane of the model grid.

"Failure in Polymeric Materials," W. G. KNAUSS, Graduate Aeronautical Laboratories, California Institute of Technology, Pasadena, California

While the problem of failure of the conventional engineering metals has interested many investigators in the past, the increasing importance of plastics and rubbery materials in engineering design has called for an extension of the existing fracture knowledge to polymers. The main feature encountered in such an extension is the more pronounced rate and temperature dependence of the failure properties in polymeric materials as compared to normal engineering metals. Indeed, one may look upon these viscoelastic polymers as materials forming the transition between the more or less rigid metals and the viscous fluid. This affinity is reflected in the approaches to the investigation of failure in polymers. As in metals, efforts are being spent on the phenomenological description of fracture as well as on the microscopic and molecular aspects of the failure process. The work of investigators in these two areas will be reviewed. Emphasis will be placed on work presently conducted at the California Institute with respect to the time dependence of the failure process.

Using existing information on the energetics of the rupture process and the concept of the presence of weak spots in a polymer continuum a failure criterion is derived which includes the effects of the time-temperature superposition principle through an Arrhenius type rate law. Application to the uniaxial tensile test at constant

strain rate gives good agreement with experiment over the whole range of strain rates tested for both an unfilled and filled rubber. Although the criterion has been tested for only the uniaxial test it is applicable to any other test condition and strain history, including stress and temperature cycling.

"Mathematical Description of the Stress Strain Behavior of Filled Binders," FRED H. BROCK, Aerojet-General Corporation, Azusa, California

This paper describes the result of a phenomenological study in the analysis of uniaxial and biaxial tensile behavior of a variety of filled systems, and a correlation that appears to serve as a tensile failure criterion for most of the systems that have been investigated. The area under the stress-strain curve, W , assumed to be equal to the stored energy function, has been found to obey the relation $W = A (1 - \exp - B(Q - 3))$, where A and B are constants, and Q is related to the first strain invariant. For a given system, the total stored energy up to break, divided by A , appears to have a constant value that is independent of strain rate and temperature. This constancy has also been verified by an independent set of data.

"Effect of Hydrostatic Stress on Plastic-Elastic Resilience of a Heterogeneous Porous System," I. K. KOTHARI* and J. A. VOMCIL, University of California, Davis

An organic soil, Staten peaty muck, containing 30 percent organic matter was used as a heterogeneous porous system. It was subjected to hydrostatic (tension) stresses of 0.0 (saturated), 0.10, 0.30, 1.0, 3.0, 10.0 and 15.0 atmospheres as well as air drying for initial moisture content equilibration. The system was then subjected to compressive stresses of 5, 10, 15, 20, and 28 psi. Compressive and resilient plasto elastic deformations were measured using a LVDT (Linear Variable Differential Transformer) coupled to a modified Taylor compression apparatus.

The total compressive deformation had two components (1) instantaneous deformation followed by (2) gradual or retarded deformation. The resilience also had similar components. However, the total resilience in almost all cases was found to be approximately equal to the retarded compressive component. On repeating the external stress cycle, the elasticity of the sample was found to increase.

CHANGES IN THE BY-LAWS

The following changes in the By-Laws of the Constitution of the Society of Rheology were approved by a majority of those voting in a mail ballot to the members in November, 1962.

Article III

Section 1 will now read:

Regular Members of the Society shall pay annual dues of \$10.00 in advance. Each member shall be entitled to subscription to the official publications of the Society.

* Present address, Carver Foundation, Tuskegee Institute, Alabama

Section 2 paragraph 1 will now read:

Sustaining Members shall pay dues of \$25.00 annually as a minimum, payable in advance and shall be entitled to the official publications of the Society.

MEETING IN AUSTRALIA

TEWKSBURY SYMPOSIUM ON FRACTURE 1963

The faculty of Engineering of the University of Melbourne will hold a Symposium on the subject of "Fracture" during the week 26th to 30th August, 1963. This has been made possible through a bequest of the late Mr. P. W. Tewksbury and the Symposium is accordingly to be known as the Tewksbury Symposium on Fracture, 1963.

Professor A. H. Cottrell, Professor of Metallurgy at the University of Cambridge (England), will deliver the Tewksbury lecture, the opening address of the Symposium. About 20 invited papers will be presented over a period of four days and ample time will be available for discussion. The papers will be preprinted and later will be published in book form with a summary of the discussion.

Subjects to be treated in papers include the physics of fracture in metals and in non-metallic materials including ceramics, plastics, concrete and natural rocks. Two papers will treat aspects of fracture in structures and special sessions will be held on the application of fracture theory to ore-dressing and to the machining of metals and other materials.

Organization of the Symposium is in the hands of a committee consisting of Professors A. J. Francis (Engineering) (Convenor), H. W. Worner (Metallurgy), and H. H. Dunkin (Mining), Mr. N. L. Svensson (Mechanical Engineering) and Dr. C. J. Osborn (Organizing Secretary).

MINUTES OF ANNUAL BUSINESS MEETING OCTOBER 30, 1962 AT JOHNS HOPKINS UNIVERSITY

The meeting was called to order by the President, J. D. Ferry at 4:00 p.m. About 40 members were present.

The minutes of the previous annual business meeting held in Madison, Wisconsin, October 31, 1961, were approved as published in Spring 1962 issue of the Bulletin.

The Annual Interim Report of the Secretary-Treasurer was read (printed elsewhere in this Bulletin). It was pointed out by the Secretary-Treasurer that deficits of at least \$600 were to be expected for 1962 and 1963 because of increased publishing costs for the Rheology Bulletin and the Transactions.

The Executive Committee on October 28, 1962 after reviewing the finances of the Society and the increasing publishing problems voted to submit to a mail ballot an increase of dues for Regular Members to \$10.00 and the deletion of the subscription to the Journal of Applied Physics from the privileges of Sustaining Members.

After some discussion on the number and support of Sustaining Memberships, a motion reaffirming the action of the Executive Committee on the mail ballot was made by Dr. J. Elliot and seconded by Mr. W. Willets. The motion passed.

Dr. Thor Smith announced that the second annual West Coast Regional Meeting would be held on January 31, and February 1, 1963 at the Shell Development Laboratory. The meeting held last year at Cal. Tech. was reported as very successful.

It was announced that the Annual Meeting of the Society of Rheology would be combined with the International Congress on Rheology to be held at Brown University August 26 to 30, 1963. A business meeting for the Society will be scheduled during this week.

Dr. R. S. Marvin, co-chairman of the International Congress Steering Committee reported on the progress in setting up the Congress. He asked that members pick up questionnaires at the registration desk and return them in order to obtain some preliminary data on the number of people who planned to attend and how many papers to expect. He also suggested that many of the invited speakers from other countries would be available for visiting industrial laboratories.

President Ferry expressed the Society's gratitude to Johns Hopkins University for providing the meeting facilities, to Prof. Ericksen for the excellent planning and to Dr. E. A. Collins for the program.

The meeting was adjourned at 4:30 p.m.

Respectfully submitted,
JOHN C. MILLER
Secretary-Treasurer

1962 INTERIM REPORT OF THE SECRETARY-TREASURER

1. FINANCIAL

A tentative record of income and disbursements is attached. The statement is approximate because disbursements after June 1962 are estimated. The working balance at the end of the year does not include collection of 1963 dues. Due to confusion about the number of members in the Society in 1961 the income is not as large as anticipated. Expenditures have risen sharply in publications and will undoubtedly continue to increase. This includes costs of both the Transactions and Bulletins. Estimated increase in costs of Transactions is \$500.

Because of increases in publication costs, postage and services, disbursements will exceed income for this year and next. Fortunately, the reserve built up over the past three years will carry the Society for a limited time. Immediate action on a dues increase will be necessary to bring income and disbursements into balance. In view of the deficits for the 1962 and 1963, new expenses should be carefully considered.

2. MEMBERSHIP

Dr. Armand Lewis is the present Chairman of the Membership Committee and under his direction the membership has grown to 660.

3. PUBLICATIONS

Two issues of the Bulletin and Volume VI of the Transactions have been published and sent to members of good standing for 1962. There have been difficulties in dues billing and circulation for 1962 which have caused considerable confusion. It is expected most of the problems will be gone by the end of 1962.

4. ANNUAL MEETING FOR 1962

Professor J. L. Ericksen is in charge of the arrangements for the meeting at Johns Hopkins University with Dr. Edward Collins serving as Program Chairman. A program and registration blanks were sent to the membership in October. The Bulletin with abstracts of the papers was distributed in October.

5. WEST COAST MEETING IN 1962

In February of this year, a two-day meeting of the West Coast Section was held at the California Institute of Technology. The meeting was a success both technically and financially. Dr. Thor Smith was the Program Chairman with Dr. Paul Blatz and Dr. Kenneth Bills handling the arrangements.

6. EXECUTIVE COMMITTEE MEETING

Two meetings of the Executive Committee were held on January 19 and October 28, 1962. Subjects for discussion included future meetings, a file of Rheology Bulletins, visiting rheologists, the 1963 International Congress and the problem presented by the large number of papers submitted for the annual meeting.

7. AMERICAN INSTITUTE OF PHYSICS

Messrs. Miller and Ferry attended the meeting of the Governing Board on March 24, 1962. Messrs. Miller and Bergen attended the Society Officers and Corporate Associates meeting held at Arden House on September 26-28. The formal meeting of the Corporation was held in February and we were represented by proxy (Dr. Elmer Hutchisson and Miss Mary Johnson). During the past year, a substantial expansion of the Institute's facilities in New York has been made through an addition to the Institute building.

The Institute has had some major difficulties in the new business systems installed in 1961. The result has been a number of members were not sent dues bills, and some paid dues but did not receive publications. A concerted effort by A.I.P. is being made in the last three months of 1962 to obtain an up-to-date file of members for circulation. If you have not received a dues bill, please contact the Secretary-Treasurer.

The Institute has handled all our dues bills, mailings, bookkeeping, etc., for 1962.

8. ACKNOWLEDGMENTS

The Secretary-Treasurer wishes to emphasize that his duties are extra-curricular and a few delays in handling correspondence, minutes and meeting notices do occur because of business duties. Every attempt is made to handle Society business promptly. The Secretary-Treasurer wishes to acknowledge the cooperation of his Company management in providing minor expenses, facilities and secretarial aid necessary for the Society operations.

The Secretary-Treasurer also thanks the Executive

Committee, committee chairmen, members and the American Institute of Physics for their cooperation.

Respectfully submitted,
JOHN C. MILLER
Secretary-Treasurer

ESTIMATED BUDGET 1963

Receipts

Balance December 31, 1962 \$3,723
 Dues for 1963 3,900

\$7,623

Disbursements

Bulletins \$1,000
 Transactions Vol. VI 2,700
 Membership Committee 100
 AIP Dues Collection 350
 AIP Contributions 100
 Membership U.S. Nat. Com. Theor. &
 App. Mech. 100
 Meeting Expenses 100
 Miscellaneous 200

\$4,650

Estimated Balance December 31, 1963 \$2,973

JOHN C. MILLER
Secretary-Treasurer

October 30, 1962

AMERICAN INSTITUTE OF PHYSICS, INCORPORATED for SOCIETY OF RHEOLOGY

STATEMENT OF ACCOUNT AT DECEMBER 31, 1962

Balance in account, January 1, 1962 \$ 5,094.35
 Income:

Dues collected, January 1-December 31, 1962:

1961 Dues \$ 12.00
 1962 Dues 3,250.80
 1963 Dues 2,495.20 \$5,758.00

Interest on U.S. Government Bond 38.74
 West Coast Regional Chapter Meeting 101.52
 Income from 1961 meeting 139.96
 Annual Meeting 535.96 6,574.18

\$11,668.53

Expenses, January 1-December 31, 1962:

A.I.P. charge for collecting dues \$ 511.29
 Contribution to A.I.P. 206.16
 Membership Committee:
 Letterheads and forms \$ 56.16
 Miscellaneous 26.79 82.95

Spring Bulletin, Vol. 31, No. 1:
 Printing \$ 290.88
 Addressing, stuffing, and mailing 15.05
 Postage 29.24 335.17

Fall Bulletin, Vol. 32, No. 2:
 Printing \$ 580.42
 Envelopes, addressing, stuffing, and
 mailing 23.90
 Postage 20.23 624.55

Transactions (Vol. 6)—Printing \$2,240.00
 Directory—preparation, printing,
 folding, and mailing (800) 305.34
 Envelopes 11.35
 Postage 95.38 2,652.07

Fall Meeting announcement:
 Preparing (including supplies) \$ 29.70
 Addressing, stuffing, and mailing 42.73
 Postage 19.85 92.28

Expense of West Coast Meeting 70.45
 Constitution amendment and ballot
 mailing:
 Preparation and supplies \$ 25.03
 Addressing, stuffing, and mailing ... 27.09
 Postage 26.13 78.25

Dues to American Society of Mechanical Engineers 100.00
 Bingham Medal 7.55 4,760.72

Balance in account, December 31, 1962 \$ 6,907.81

Bingham Fund:
 U.S. Government Bond—3 $\frac{7}{8}$ % due 5/15/68 \$ 1,000.00

February 19, 1963