RHEOLOGY BULLETIN

Publication of the Society of Rheology

Volume 33, No. 1 — January, 1964

FIRST WINTER MEETING OF THE SOCIETY OF RHEOLOGY

Claremont University Center
Claremont, California
February 3 and 4, 1964

Location: Claremont is 24 miles east of Pasadena and 40 miles from the Los Angeles International Airport. Technical Sessions of the meeting will be held in the Baxter Science Laboratory Building, at 11th and Columbia Avenue.

The Claremont Inn (15 rooms available) is within walking distance of the meeting auditorium. Reservations can also be made at the Holiday Inn in Montclair (taxi fare from the Holiday Inn to the Claremont Inn is about $1.00). Another nearby motel is the Uplander. Persons arriving at the Los Angeles International Airport can take a limousine from the Airport to the Holiday Inn in Montclair. If you drive, please stay at the Holiday Inn.

Papers presented at the Winter Meeting of The Society can be published in Transactions of The Society of Rheology. Two copies of manuscripts should be sent to Thor L. Smith, Stanford Research Institute, Menlo Park, California, to arrive before February 17. It is anticipated that the volume of the Transactions which contains these papers will appear before the end of 1964.

Professor Leonard Dart of the Claremont Men's College is in charge of local arrangements.

NOTICE OF ANNUAL MEETING

October 26-28, 1964

The 35th annual meeting of the Society will be held at the Mellon Institute, Pittsburgh, Pennsylvania on October 26-8, 1964.

Correspondence regarding the submission of papers should be conducted with Program Chairman Krieger, whose address appears below.

SOCIETY OF RHEOLOGY OFFICERS 1964-1965

President

JAMES T. BERGEN, Armstrong Cork Company, Lancaster, Pa.

Vice-president

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

Secretary-treasurer

JOHN C. MILLER, Union Carbide Plastics Company, Bound Brook, N. J.

Editor

RAYMOND R. MYERS, Department of Chemistry, Lehigh University, Bethlehem, Pa.

Committee Chairmen, 1964

Program

IRVIN M. KRIEGER, Department of Chemistry, Case Institute of Technology, Cleveland 6, Ohio

Bingham Award

JOHN D. FERRY, Department of Chemistry, University of Wisconsin, Madison, Wisc.

Membership

ARMAND F. LEWIS, Stamford Research Laboratories, American Cyanamid Company, Stamford, Conn.

EXECUTIVE COMMITTEE

This committee is composed of the officers plus Immediate Past Chairman Ferry and two members elected at large: Thor L. Smith, Propellant Research & Development, Stanford Research Institute, Menlo Park, Calif., and Hershel Markovitz, Mellon Institute, Pittsburgh 13, Pa.

RHEOLOGY BULLETIN
Raymond R. Myers, Editor
Department of Chemistry
Lehigh University
Bethlehem, Pa., 18015

PROGRAM
WINTER MEETING
THE SOCIETY OF RHEOLOGY
February 3-4, 1964

CLAREMONT UNIVERSITY CENTER
BAXTER SCIENCE LABORATORY
11th & Columbia Avenue, Claremont, California

8:15-8:45 Registration

8:45-8:50 Opening of Meeting

Thor L. Smith, Stanford Research Institute

8:50 Technical Session
Chairman, Roger S. Porter, California Research Corporation, Richmond, California

9:00-10:00

INVITED LECTURE. *"A Discussion of the Molecular Theories of Viscoelastic Behavior of Rubberlike Polymers,"* ROBERT S. MARVIN, National Bureau of Standards, Washington, D. C.

The Rouse theory of the viscoelastic behavior of rubberlike polymers in shear has been modified to include entanglement effects, and the influence of molecular weight on this behavior has been studied (Marvin and Oser, J. Res, NBS, *66B*, 171, (1962); Oser and Marvin, ibid, *67B*, 87 (1963)). This theory is based on a model, the form of which can be shown to be one of the several equivalent formulations for linear viscoelastic behavior. It is a molecular theory in the sense that its parameters can be obtained from the molecular weight, the entanglement molecular weight, and the monomeric friction coefficient. If appropriate averages can be defined, and if our current ideas relating viscosity to entanglements and free volume are correct, the model should predict the behavior of polymers with a distribution of molecular weights.

The same type of model should predict viscoelastic response in dilatation. In this case, entanglements are not expected to play a role, nor indeed do we expect that the whole of even rather short polymer chains would participate in cooperative motions. The formulation for bulk compliance introduces both the high and low frequency limiting compliances as parameters. The role of the model here is primarily one of relating the influence of time, temperature, and pressure in the transition region between these two limits to the monomeric friction coefficient.

10:15-10:45

"The Intrinsic Viscosity of Coiling Macromolecules," ROBERT ULLMAN, Scientific Laboratory, Ford Motor Company, Dearborn, Michigan

The intrinsic viscosity of coiling molecules has been calculated using the Kirkwood-Riseman adaptation of the Oseen approximation. Four different models of chain segment distribution were treated: (1) A Gaussian coil; (2) an excluded volume model of Kurata and Yamakawa (J. Phys. Soc. Japan *13*, 78 (1958)); (3) a coil expansion model suggested by Peterlin (J. Chem. Phys. *23*, 2464, (1955)); and (4) an excluded volume model deduced from the machine computation of Wall and Erpenbeck (J. Chem. Phys. *30*, 634 (1959)). In all cases the partially free draining coil was treated. The mathematical solution of the problem has been carried out on an IBM 704 Computer.

The Kirkwood-Riseman procedure used in these calculations depends upon the assumption that the detailed Brownian motion of a polymer molecule may be replaced by the average velocity of the polymer segments, and that the hydrodynamic interaction tensor may be replaced by its average over-all directions. The effect of these approximations on the intrinsic viscosity of a rigid rod molecule is likely to be greater than for coiling molecules, and the calculation can be carried out. It is shown that the calculated intrinsic viscosity of a rigid rod molecule is unaffected by the Brownian motion approximation, and is reduced at most by a factor of 15/16 by using a directional average of the hydrodynamic interaction tensor in the governing equations.

10:45-11:15

"The Hydrodynamic Behavior of Fully Acetylated Guaran," JOSEPH V. KOLESKE and SHELDON F. KURATH, The Institute of Paper Chemistry, Appleton, Wisconsin

The guaran molecule is a high molecular weight polysaccharide consisting of a β-1, 4-linked mannose main chain with an α-1, 6-linked galactose side group on every other mannose unit. The viscosity and light scattering behavior has been investigated in the weight average D. P. range of 171 to 12,400. Analysis of the viscosity-molecular weight behavior in terms of the hydrodynamic theory of Kurata and Yamakawa indicate that at high molecular weights the polymer is nondraining and that excluded volume effects are unimportant. Equivalent bond lengths calculated from intrinsic viscosity and from light scattering indicate that it is necessary to dis-

tinguish between the hydrodynamic and light scattering radius-of-gyration. The Flory coefficient calculated on the basis of the light scattering radius-of-gyration is less than the recent theoretical value of $\Phi' = 4.20 \times 10^{22}$ and decreases with decreasing molecular weight. When the hydrodynamic radius of gyration is used the Flory coefficient is found to be, $(\Phi') = 4.28 \pm 0.67 \times 10^{22}$, in good agreement with theory.

11:15-11:45

"Melt Viscosities of Multi-Chain Polybutadienes," GERARD KRAUS and J. T. GRUVER, Phillips Petroleum Company, Bartlesville, Oklahoma

The introduction of one or two long chain branches into polybutadiene molecules to form tri-chain or tetra-chain molecules, respectively, leads to profound changes in rheological behavior. At low molecular weights the Newtonian viscosity is decreased relative to a linear polymer of the same molecular weight, in agreement with the work of Fox and Allen on polystyrenes and Flory and Schaefgen on poly (ϵ-caprolactams). At molecular weights exceeding 60,000 (tri-chain) or 100,000 (tetra-chain) the Newtonian viscosity rises rapidly above the corresponding value for a linear polybutadiene. However, non-Newtonian behavior of the branched polymers becomes more pronounced the higher the molecular weight, so that at moderate to high shear rates the viscosity of the branched polymers is uniformly lower than that of linear polymers of identical molecular weight.

11:45-12:15

"The Flow of Moderately Concentrated Polymer Solutions in Water," F. RODRIGUEZ and L. A. GOETTLER,* Geer Laboratory for Rubber and Plastics, School of Chemical Engineering, Cornell University, Ithaca, New York

The flow curves for four water-soluble, non-ionic polymer types have been characterized using rotational viscometers primarily. Molecular weight and solution concentration variations gave a total of twenty-five curves. Polyacrylamide, poly(ethyleneoxide), hydroxyethyl cellulose, and methyl cellulose were studied. A two-parameter model that gives a good fit to the data over five decades of shear-rate is:

$$\frac{\log(\eta r)}{\log(\eta r)_o} = 0.68 - 0.32 \operatorname{erf} \frac{\operatorname{Log}(\tau\dot{\gamma}) - \log B}{2.27\sqrt{2}}$$

In this equation, ηr is the relative viscosity; ηro, the same at zero shear-rate, erf, the error function; $(\tau\dot{\gamma})$, the rate of energy dissipation; and, B, the value of $(\tau\dot{\gamma})$ at the inflection point of the flow curve. Furthermore, B is independent of concentration.

Monday Afternoon, February 3, 1964

Chairman, R. F. Landel, Jet Propulsion Laboratory

1:45-2:45

INVITED LECTURE. *"Mechanical Behavior of High Polymers,"* G. W. BECKER,* Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

*Present address: Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California

A concentrated survey will be given of investigations which have been carried out in the German Physikalisch-Technische Bundesanstalt during the last few years. Besides some general investigations of the viscoelastic behavior of polymers, the nonlinear behavior of filled and crystalline materials as well as the elastic properties of foams will be treated. Theoretical descriptions of the results, which have been extended by new data, will be discussed.

2:45-3:15

"Analysis and Interrelation of Stress-Strain-Time Data for Asphalt Concrete," K. E. SECOR, Civil Engineering Dept., Chico State College, Chico, Calif., gineering Dept., Chico State College, Chico, California, and C. L. MONISMITH, Civil Engineering Dept. and Institute of Transportation and Traffic Engineering, University of California, Berkeley, California

Test data are presented for an asphalt concrete subjected to creep, stress-relaxation and constant rate-of-strain in compression at 40° F. Because of the extreme difficulty in obtaining a perfect step-function input of strain in the relaxation tests, it was necessary to accept and utilize data exhibiting some variation of strain with time. The relaxation modulus-time relationship was obtained from these results by means of a numerical application of the superposition principle. The same numerical technique used to reduce the relaxation test data was employed to compute a similar relaxation modulus-time relationship from the results of the constant rate-of-strain tests. Another numerical procedure was utilized to interconnect tests values for creep compliance vs. time to provide a third relaxation modulus-time relationship. Both numerical solutions noted above were accomplished with the aid of an IBM 7090 computer. A comparison of the results for the relaxation modulus vs. time derived from the three different tests showed a correlation sufficiently satisfying to warrant continued study along such lines.

3:30-4:00

"Solid Propellant Dynamic Properties and Their Effect on Vibration Response of Model Solid Propellant Structures," G. J. KOSTYRKO, Aerojet-General Corporation, Sacramento, California

Three types of vibration tests have been improved and applied to the laboratory measurement of the dynamic mechanical properties of solid rocket propellants over the range of 0.1 to 300 cps. These include a free-vibration reed test, free-vibration torsion tests, and a forced-vibration disc test. Computer techniques, based on linear viscoelastic theory, have been devised or improved to yield complex elastic moduli and loss tangents. Both temperature and frequency influence dynamic properties. The Williams-Landel-Ferry time-temperature superposition

principle is applicable. The relationship between reduced resonance frequency and temperature is proposed as a fundamental and useful property of a material. This relationship, obtained from tests on laboratory specimens, appears to be applicable to the prediction of the effect of temperature changes on the dynamic response of missiles.

4:00-4:30

"On The Behavior of Second-Order Fluids in Nonsteady Simple Shearing Flows," B. D. COLEMAN, R. J. DUFFIN, and V. J. MIZEL, Mellon Institute and Carnegie Institute of Technology, Pittsburgh, Pa.

We here discuss questions of uniqueness, stability, and existence for the partial differential equation describing the velocity field of a second-order fluid engaged in a nonsteady simple shearing flow in a channel with moving boundaries. Assuming that the coefficient γ of the second Rivlin-Ericksen tensor, in the constitutive equation for the stress, is negative, we obtain theorems of the following type. The initial value problem with specified boundary values has, in general, at most one bounded solution. For channels of sufficiently small width we have a stronger and somewhat surprising result: There is at most one bounded solution for each prescription of velocities of the boundaries *regardless of initial conditions.* This latter result, when combined with some observations on existence of bounded and unbounded solutions, implies that all existing solutions of boundary value problems are unstable.

4:30-5:00

"The Recursive Theory of Slow Viscoelastic Flow, Applied to Three Basic Problems of Hydrodynamics," W. E. LANGLOIS, IBM Reseach Laboratory, San Jose, California

The flow-field and stresses, correct to the third order, are calculated for three basic problems of viscoelastic flow: the Poiseville problem; helical flow in an annulus; torsional flow between discs. The slow flow equations are set out in general tensor notation, then specialized to cylindrical polar coordinates and to spherical polar coordinates.

Tuesday Morning, February 4, 1964

9:00 - 12:15

Chairman, P. J. Blatz, California Institute of Technology

9:00-10:00

INVITED LECTURE. *"Rheological Aspects of Polymer Adhesion,"* D. H. KAELBLE, Central Research Laboratory, Minnesota Mining and Manufacturing Company, St. Paul, Minnesota.

The adhesive properties of polymers are related to their chemical composition, structure, and free volume. Measureable values of surface free energy are correlated with cohesive energy density. Influence of surface roughness in increasing the apparent surface energy and adhesion of low energy surfaces is reviewed. The conditions of molecular relaxation and flow which permit application of the thermodynamic criteria to bonding are described. The influence of test methods on apparent strength of adhesive joints is summarized. The relations of polymer structure to cohesive properties are discussed. The cohesive and joint strength properties of elastomers and thermoset resins are compared in corresponding states of network entropy and molecular free volume. The interfacial adhesive properties of polymers are related to cohesive properties in terms of rheological and structure concepts.

10:15-10:45

"Tensile Creep of Polystyrene at Elevated Temperature," H. KARAM and J. BELLINGER, The Dow Chemical Company, Midland, Michigan

The tensile creep behavior of polystyrene was studied at elevated temperature of 70°C-240°C. The paper will describe in detail experimental techniques and apparatus to obtain the zero shear viscosity of the polymer in this temperature range. Data will be compared with similar information obtained by other experimental techniques. Possible explanations for the discrepancies in the two sets of data are discussed. The paper will indicate, however not in detail, how one can obtain melt elasticity, creep function and compliance function of an amorphous polymer in the temperature range of 70°C to 240°C by creep experiments.

10:45-11:15

"Degree of Immobility — An Atomistic Approach to the Viscosity of Concentrated Suspensions," T. W. GILLIS, Lockheed Propulsion Co., Redlands, Calif.

A review of the atomistic interpretations of the viscosity of concentrated suspensions is made. The degree of immobility of the suspending media is shown to be a function of the degree of dispersion and surface energy of the solids. The layer of immobilized liquid is shown to be limited by the proximity of the suspended particles to each other. Both aqueous and nonaqueous suspensions are treated.

11:15-11:45

"The Measurement of Propellant Rheology," JOHN HEPWORTH, E. B. CHRISTIANSEN, and S. T. HOLBROOK, Thiokol Chemical Corp., Wasatch Div., Brigham City, Utah

The need for not only a consistent and accurate viscosity measurement, but the necessity for a correlation between these measurements and the successful casting of rocket motors is discussed in this paper. Several instruments are described for use in measuring propellant rheological properties. Both the advantages and disadvantages are given along with the implications derived from these advantages or disadvantages. Rheological data of propellant and

high-solid-contained slurries are presented from the following rheological instruments: (1) Brookfield viscometer; (2) modified Severs extension rheometer; (3) tube-flow viscometer; (4) internal orifice viscometer; and (5) modified Brabender Plastograph-type viscometer.

11:45-12:15

"Flow of Gelling Materials in a Uniform Layer on a Vertical Plane," F. J. FISCHER and P. R. PASLAY, Mechanical Engineering Dept., Rice University, Houston, Texas

In this paper the motion of a general class of gelling materials was investigated under a particular physical configuration. The gelling material was hypothesized to be a Bingham type body of constant viscosity and variable critical shear stress. The form of the time-past deformation dependent critical shear stress has been proposed by Slibar and Paslay and incorporates an expotential memory function, which "weights" current deformation rates more heavily than those occurring at a previous time. The general constitutive equations used in this study were also proposed earlier by Slibar and Paslay and in essence infer that no motion within the body is permissible for values of the square root of the quadratic invariant of the reduced stress tensor less than the critical shear stress.

The physical configuration treated is that of a uniform layer of the proposed material extending over an infinite vertical plane. Hence, the stress field is a function of the material density and layer thickness only. The steady-state solution was found for incipient flow and the necessary and sufficient criteria for solidification of the flow was determined.

Tuesday Afternoon, February 4, 1964

Chairman, A. San Miguel, Jet Propulsion Laboratory

1:45-2:15

"Stretching of Elastic Tubes Over Rotationally Symmetric Mandrels," R. A. WESSLING and T. ALFREY, JR., The Dow Chemical Company, Midland, Michigan

An analysis of the stretching of cylindrical tubular elastic membranes over rotationally symmetric mandrels has been carried out. The equation of equilibrium is developed by obtaining a force balance on an element of the tube. Forces acting on the element are membrane stresses, normal forces exerted by the mandrel on the tube, and tangential forces arising from the frictional resistance to motion. The equation is formulated in terms of extension ratios for convenience in handling nonlinear material properties. The tube is assumed to be perfectly elastic. Two types of material properties are considered: Hookean elasticity for small deformations and Mooney-Rivlin elasticity for large deformations.

The general analysis has been applied to the case of a conical mandrel. This system is geometrically simple but retains all the essential features of the general case. The analysis leads to a differential equation in the extension ratios. An exact solution can be obtained by assuming Coulombic friction and Hookean elasticity. The Mooney-Rivlin theory leads to a differential equation which can only be solved numerically. The results were checked experimentally. A rubber tube was pulled slowly over a Teflon cone and the resulting biaxial stretching was measured. The data were plotted in extension ratio "space." A theoretical trajectory was plotted using the measured friction coefficient and material properties of the rubber. The results are in good agreement.

2:15-2:45

"Composite Viscoelastic Cylinders," R. L. TAYLOR and D. D. MILLERICK, University of California, Berkeley, California

This paper is concerned with axisymmetric deformations of composite, thick-walled circular cylinder in plane strain. The cylinder considered is assembled from a finite number of concentric elements bonded together to form a continuous, composite assemblage. The analysis considers each elemental cylinder individually; thus, material properties may change from one element to the next. Proceeding from the equilibrium and strain-displacement equations, and adopting constitutive equations appropriate for isotropic, linear viscoelastic solids, the displacements at the boundaries of each element are determined for unit step pressures applied independently to each boundary. Such displacements constitute influence functions for arbitrary pressures applied to the boundaries of each element. Satisfying the equilibrium and the continuity conditions at each of the interfaces between elements leads to a system of simultaneous, linear integral equations which are analogous to the Maxwell-Mohr equations obtained in elastic analysis. The solution of these equations yields the pressures at each interface and, subsequently, the stresses throughout the cylinder. Displacements may be calculated directly from these results. An illustrative numerical example is included to demonstrate the method.

2:45-3:15

"Biharmonic Solution of Certain Integro-Differential Equations of Linear Viscoelasticity," ALEXANDER S. ELDER, Ballistics Research Lab., Aberdeen Proving Grounds, Md.

A stress function for linearly viscoelastic solids is developed. If body forces and inertial terms are neglected, the stresses may be expressed in terms of Maxwell stress functions. The displacements are expressed directly in terms of harmonic functions through an extension of the Neuber-Papkovitch theory. Axially symmetric stresses and strains are given in terms of a single biharmonic function The analysis

does not involve boundary conditions and is valid for problems involving moving loads and moving boundaries. The theory may be used to formulate stress analysis problems in terms of Volterra integral equations using creep or relaxation functions as the kernel. The integral equations governing the stresses in a viscoelastic propellant grain subjected to the combined effects of internal pressure and erosion are derived.

3:30-4:00

"A Linear Viscoelastic Stress Function for Problems Involving Torsion Free Axisymmetry," JAMES R. CLEMENTS and TERRELL M. JONES, Thiokol Chemical Corporation, Alpha Division, Huntsville, Ala.

A stress function developed by Southwell for linear elastic problems involving torsion free axisymmetry has proven itself to be well suited for finite difference solutions in the solid propellant industry. Such solutions have been used in conjunction with the elastic-viscoelastic correspondence principle to develop solutions for linear viscoelastic problems having the same boundary conditions. A linear viscoelastic equivalent to the Southwell stress function is presented. Such a stress function could allow the direct solution of a viscoelastic problem without resorting to approximate Laplace transform inverse techniques. It is shown that the stresses derived from the viscoelastic stress function satisfy the equilibrium equation and the stress equations of compatibility for linear viscoelastic material. The constitutive equations are expressed in the form of linear Stieltjes convolution integrals. The results are illustrated by applications to special cases.

4:00-4:30

"Thermodynamics of Polymer Solutions," P. J. BLATZ, California Institute of Technology, Pasadena, Calif.

The heat of mixing of a polymer with a solvent is a sensitive function of the concentration of polymers. The thermodynamic prediction of this behavior depends on the form of the heat of interaction. For random mixing, we have

$$[\overline{X}/(Nv_1 - \overline{X})]\ [\overline{X}/(Nv_2 - \overline{X})] = 1 \qquad (1)$$

where $\overline{X}$ is the number of polymer-solvent interactions in a quasi-crystalline lattice, N is the total number of lattice points, v_1 and v_2 are respectively the volume fractions of solvent and polymer. Solution of Eq. (1) leads to the Hildbrand-Scatchard expression: $\overline{X} = Nv_1v_2$ which was used by Flory and Huggins in their statistical treatment of polymer solutions. For quasi-chemical mixing, we have:

$$[\overline{X}/(Nv_1 - \overline{X})]\ [\overline{X}/(Nv_1 - \overline{X})] = \exp(-2B_{12}V_1/zkT) \qquad (2)$$

which leads to

$$\overline{X} = 2Nv_1v_2/(1 + B) \qquad (3)$$

$B^2 = 1 + 4v_1v_2(n^2 - 1)$, and $n = \exp(B_{12}V_1/zkT)$

where B_{12} is the cohesive energy density of the mixture, V_1 is the molal volume of solvent, and z is the lattice number. It is shown that Eq. (3) leads to an expession for the heat of mixing which predicts fairly well the data presented by Treloar on the heat of dilution of rubber by benzene.

4:30-5:00

"Some Observations on the Sorbtion of Moisture by Elastomeric Propellant Binders," J. C. POTTS, Aerojet-General Corporation, Sacramento, California

As part of a study of the effect of moisture on solid propellants, the sorbtion isotherms of six binders, made from a variety of commercial materials, have been determined at room temperature. The χ_1 interaction parameters and the corresponding heats of dilution have been calculated. All six isotherms are concave upward. In the low solubility range isotherms of this shape are not well represented by the Flory-Huggins equation so the use of a semi empirical equation which fits them all is suggested.

SOCIETY OF RHEOLOGY
ANNUAL BUSINESS MEETING
Brown University
August 29, 1963

1. The meeting was called to order at 5:00 P.M. by President Ferry with approximately 50 members present. The minutes of the previous annual business meeting were approved as printed in the 1963 Spring Bulletin.
2. The Interim Report of the Secretary-Treasurer was presented (published elsewhere in this Bulletin). The Secretary-Treasurer estimated the deficit this year to be substantially less because the cost of the Transactions was lowered.
3. President Ferry announced that by Executive Committee action the Society will sponsor the West Coast Meeting in Claremont, California, February 3-4. To provide publication for papers presented at the second Regular Meeting, a second issue of the Transactions will be published next year.
4. W. R. Willets suggested that with the complications of two meetings and two Transactions the duties of the Secretary-Treasurer should be divided between two offices.
5. Two suggestions were made from the floor with respect to publications policy: 1) that more stringent requirements on authors could keep the number of pages down; and 2) the overflow from the technical meetings could be forwarded to Rheologica Acta for publication.
6. J. H. Elliot proposed changes in the Constitution and By-Laws which will simplify the Society operation and define two membership classes in the Society: Regular members and Sustaining members. Regular membership will be restricted to individuals. It was moved, seconded and voted to

present the changes to the membership by mail ballot.

7. President Ferry announced that because of Constitutional restrictions on elections procedure, the election results would not be complete until October 1. (Election results appear on page 1).

   Vice President J. T. Bergen presented a proposed change in the Constitution which will provide some flexibility in the election procedure. Instead of fixed dates, i.e., May 15, the Constitution will be changed so that ballots will be returned a specified number of days before the Annual business meeting. It was moved, seconded and voted to submit the proposed change to the membership by mail ballot.

8. The following resolutions were presented by J. T. Bergen and were voted by acclamation:

   Resolved: That the Society of Rheology recognize gratefully the indispensable contributions in facilities and services made to the Fourth International Congress on Rheology, by the Administration, Faculty and Staff of Brown University. Gratitude is to be extended to Barnaby C. Keeney, President of the University, and to R. Bruce Lindsay, Dean of the Graduate School, for their personal contribution to a most enjoyable and friendly evening on the occasion of the Congress Banquet. We further resolve that this expression of gratitude be duly conveyed to these individuals by the President of the Society.

   Resolved: That in recognition of the presentation of all phases of the Fourth International Congress of Rheology, the Society of Rheology hereby offers its gratitude and congratulations to: R. S. Marvin and R. S. Rivlin, as co-chairmen, and to their associates serving on the various Committees for this Congress. The gratitude of the Society is extended for the many hours of careful planning and effort which were essential to the success of the Congress; its congratulations are sincerely offered on behalf of the members who have been so well and so memorably entertained in every respect, in the course of the Congress itself. In recognition thereof, it is directed that this resolution be included in the minutes of the Society and that the President be directed to forward suitable copies thereof to the co-chairmen of the Congress.

9. Editor E. H. Lee explained the publishing policy for the International Congress. It is expected that five covers will make up Volume V. Number 1 will be a typical Transactions and will be sent to members of the Society not attending the Congress. All five covers, including two on biorheology, will be sent to all attendees of the Congress. The cost of these volumes was included in the registration fee.

10. There being no further business, the meeting was adjourned.

JOHN C. MILLER
Secretary-Treasurer

SOCIETY OF RHEOLOGY

REPORT OF SECRETARY-TREASURER

For 1963

1. The disbursements for 1963 are fairly well established and can be considered nealy correct. No deficit is expected for 1963 because the price of the 1963 Transactions was less than the price for 1962 Volume and only one Bulletin was printed this year. The savings from these two items are estimated to be $600.

   The estimated budget for 1964 includes a second volume of the Transactions to be published late in 1964. It is expected that this volume plus an expanded Bulletin will use most of the dues increase effective in 1964.

2. MEMBERSHIP

   The present membership of the Society is about 600. This is a sufficient number to give the Society two members on the Governing Board of AIP. Armand F. Lewis is responsible for our membership campaigns.

3. PUBLICATIONS

   One issue of the Rheology Bulletin and Vol. VII of the Transactions has been published and sent to members in good standing.

4. WEST COAST REGIONAL MEETING

   The West Coast Regional Meeting was held on January 31 — February 1, 1963 at the Shell Development Company, Emeryville, California. Thor Smith and Paul Blatz developed the program. The meeting facilities were arranged by the Shell Development Company. Sixteen papers were presented, three invited papers and 13 contributed papers. The meeting was financially self-supporting.

5. FOURTH INTERNATIONAL CONGRESS ON RHEOLOGY

   The Society of Rheology was the host Society for the Fourth International Congress held at Brown University, Providence, R. I. August 25 to August 30. Announcements of the Congress were sent to all members of the Society. Programs were also sent to all members in the Society in August. R. S. Marvin and R. S. Rivlin were co-chairmen for the organization of the Congress and Prof. Rivlin was in charge of the local arrangements. E. H. Lee is the Editor for the Congress; A. L. Copley the Editor and Chairman of the Symposium on Biorheology.

6. ANNUAL MEETING OF THE SOCIETY OF RHEOLOGY

   The Annual Meeting for 1963 was combined with the Fourth International Congress.

7. EXECUTIVE COMMITTEE MEETINGS

   The Executive Committee met twice this year,

on February 15 and on August 25. The major topics for discussion were the organization of the International Congress and the publication of papers presented at the Congress. Other topics were the definition of membership classes and the Annual Meeting for 1964.

8. CHANGES IN THE BY-LAWS OF THE CONSTITUTION

The following changes in the By-Laws were voted on by the membership and passed by a majority of those voting.

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.

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.

9. ELECTION OF OFFICERS

The report of the Nominating Committee was published in the Spring Bulletin. No additional nominations were received by the Secretary-Treasurer. Ballots were sent out in June with a request to return them by August 1, although ballots may be received until October 1, 1964. The Election Committee, J. B. Wlkens and F. Padden reported the following officers elected:

President:	J. T. Bergen
Vice-President:	R. S. Marvin
Editor:	R. R. Myers
Secretary-Treasurer:	J. C. Miller
Executive Committee	T. L. Smith
Members-at-Large:	H. Markovitz

10. AMERICAN INSTITUTE OF PHYSICS

All mailings, dues collection, etc., were done by the American Institute of Physics in 1963.

Dr. Miller attended the meeting of the Governing Board on March 16, 1963. The meeting of the Corporation was held in February and the Society was represented by proxy (Elmer Hutchisson and Mary Johnson).

An effort to purge and obtain up to date mailing lists of the Societies resulted in some apparent loss in membership for the Society.

ACKNOWLEDGMENTS

The Secretary-Treasurer's duties are extra curricular and sometimes correspondence is delayed because of other responsibilities. The Secretary-Treasurer wishes to acknowledge the cooperation of his Company management in providing minor expenses, facilities and secretarial help necessary to Society operations. The Secretary-Treasurer also wishes to acknowledge the cooperation of the Executive Committee, committee chairmen and the American Institute of Physics.

Respectfully submitted
JOHN C. MILLER
Secretary-Treasurer

Estimated Expenses for 1963

Balance December 31, 1963	$ 4,400
Income from Dues	3,600
TOTAL	$ 8,000
Disbursements	
A. I. P. Charges	$ 550
Bulletin (1)	365
Programs for International Congress	300
Transactions, Vol. VII	2,100
U. S. Committee on Theoretical and Applied Mech.	100
Membership Committee	100
Election	55
TOTAL	$ 3,570
Balance December 31, 1963	$ 4,400

Estimated Budget 1964

Balance December 31, 1963	$ 4,400
Income	
630 members at $10.00	6,300
	$10,700
Disbursements	
Bulletins	$ 1,200
Transactions	3,600
AIP Charges	900
U. S. National Committee on Theoretical and Applied Mech.	100
Editor's Expense	300
Membership Committee	100
Miscellaneous	100
	$ 6,300
Balance December 31, 1964	$ 4,400