RHEOLOGY BULLETIN

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Volume 40, No. 2 August, 1971

42nd ANNUAL MEETING
THE SOCIETY OF RHEOLOGY, INC.

Knoxville, Tennessee

October 25-27, 1971
University Center
University of Tennessee

Program Committee

W. W. Graessley (Committee Chairman), Chemical Engineering Department, Northwestern University, Evanston, Illinois 60201.

E. A. Kearsley, Rheology Section, National Bureau of Standards, Washington, D.C. 20234.

A. S. Lodge, Engineering Mechanics Department, University of Wisconsin, Madison, Wisconsin 53706.

B. D. Marsh, Union Carbide Corporation, Bound Brook, New Jersey 08805.

Local Arrangements Committee

J. L. White, Committee Chairman, Dept. of Chemical Engineering, University of Tennessee

D. C. Bogue, Co-Chairman

F. N. Peebles, Dean of Engineering

Symposium

A one-day symposium, the Rheology of Fibers and Spinning, will be held during the meeting on Monday, October 25. This will include invited and contributed papers on (1) experimental studies and modeling of the spinning process, (2) measurement of elongational viscosity, (3) studies of orientation and crystallization during spinning and drawing and (4) mechanical properties of solid fibers and fabrics. A. Ziabicki and A. Peterlin will present invited lectures.

Attractions

An instrument exhibit will be held in conjunction with the meeting.

There will be tutorial short course immediately prior to the annual meeting in Knoxville.

Society of Rheology Short Course

There will be a one day short course, "Elementary Problem Solving in Rheology", Sunday, October 24, 1971 immediately preceeding the Fall meeting. The instructor will be Professor R. Byron Bird of the Chemical Engineering Department of the University of Wisconsin.

The purpose of this venture is to fulfill a need for courses designed to close the gap between theory and practice of Rheology and for continuing education.

Topics to be covered include: discussion of problems which industry wants to know how to solve, the development of rheological equations, the most used rheological and thermal equations in industrial problems, special classes of flow, empirical model building, classification of flow regimes, future applications of molecular theory and exploration of the "rheology gap".

Participants are to submit a one page description of either an industrially oriented unsolved rheological problem or an example of a rheological application that they have experienced. These problems would be referred to in the course of the discussion. Thereby, student participation and interaction is encouraged. A set of notes will be sent to participants in advance of the course. Participants should have a BSc degree or equivalent.

A fee of $75 will be charged for registration for this course prior to September 7, 1971, with a late registration penalty of $25 applicable thereafter. Student rates will be one half of the regular fee. This is a new venture for the Society of Rheology; if registration is inadequate the course would be cancelled and the fees refunded.

Registration consists of the problem abstract referred to above, and a check payable to the Rheology Society.

Further information or a course outline may be obtained from M. H. Birnboim, E. A. Collins or J. L. White. Registration applications should be sent to: Prof. M. H. Birnboim, Division of Mechanics, Rensselaer Polytechnic Institute, Troy, New York 12181.

RHEOLOGY BULLETIN
Raymond R. Myers, Editor
Department of Chemistry
Kent State University
Kent, Ohio 44242

Facilities

Speakers will be provided with a blackboard and 2 inch by 2 inch and 3¼ inch by 4¼ inch slide projectors. If other facilities are required, the Local Arrangements Chairman should be contacted as soon as possible.

Publication

Authors are urged, but not required, to publish their papers presented at the meeting in the Transactions of the Society of Rheology. Manuscripts should be submitted to the editor, R. R. Myers, Chemistry Department, Kent State University, Kent, Ohio 44242. Acceptance for publication will be decided by the editor, in consultation with assistant editors for Volume 16 and referees appointed by him for each manuscript.

Instruction for Authors

Preparation of Manuscripts for Transactions

Three copies of the manuscript, of which one should contain glossy prints of the figures are required. All manuscripts should be sent to the editor who will select an assistant editor whose interests most closely coincide with that of the subject of the paper.

Any neat double-spaced copy with comfortable margins is considered acceptable form for the manuscript. Although ribbon copy is prefered, there is no objection to legible duplicated copies; 8½" x 11" sheets are preferable but not mandatory. An abstract of the article should appear on the first page of the manuscript.

1971 BINGHAM MEDALIST

The Society of Rheology will award the 1971 Bingham Medal to Professor Arthur S. Lodge of the University of Wisconsin. The presentation and banquet are to be held on Tuesday evening, October 26, during the annual meeting at the Sheraton Motor Inn. Professor Lodge has been active in rheology since 1950 when he demonstrated the utility of convected coordinates in formulating and solving flow problems. His 1956 paper on the formulation of constitutive equations from the basis of molecular network theory stimulated major activity in the molecular rheology field. His monograph "Elastic Liquids" is a lucid, scholarly, and comprehensive treatment of modern rheology, both theoretical and experimental. More recently, Professor Lodge's detailed analysis of rheological measurements resulted in the discovery of an important source of error in normal stress measurements ("the hole effect"). The Society takes pleasure in recognizing the scholarly and substantial contributions of Professor Arthur S. Lodge to the many facets of rheology by naming him the 1971 Bingham Medalist.

NOMINATIONS

Ballots, mailed in July, have the following slate:

President: F. R. Eirich, Polytechnic Institute of Brooklyn
Vice President: R. S. Rivlin, Lehigh University
W. H. Bauer, Rensselaer Polytechnic Institute
Editor: R. R. Myers, Kent State University
Secretary: J. C. Miller, Union Carbide Corporation
Treasurer: E. A. Collins, B. F. Goodrich Chemical Co.
Executive Committee at Large:
A. N. Gent, University of Akron
W. W. Graessley, Northwestern University
E. A. Kearsley, National Bureau of Standards
J. R. Knox, Amoco Chemicals Inc.

SOCIETY OF RHEOLOGY

Executive Committee Meeting
March 15, 1971

Executive Committee Present: H. Markovitz, R. Myers, F. Eirich, R. Coulehan, J. Miller, E. Collins.

Others Present: M. Birnboim

1) Minutes were approved as distributed by mail.

2) A brief summary on the Winter Meeting in Salt Lake City reported 56 registrants.

3) R. Coulehan presented preliminary plans for charter flight to Europe. The Committee suggested that August 26 to September 16, 1972 were the best dates because of a biorheology symposium which may overlap the International Congress.

4) Dr. Koch, Director of AIP, presented the new concepts in information retrieval which AIP is currently working on. Dr. Koch also reported that AIP Journals are working on a two track system to get 85% of the page charges honored.

5) Dr. Koch reported that 50% drop in physics PhD production is occurring.

6) J. L. White reported some details on the local arrangements for the Knoxville Meeting in the Fall.

7) M. Birnboim presented the results of a Short Course Committee to develop a course for the Knoxville Meeting. After some discussion a motion to supply $100 for expenses for a tutorial program of 2 to 3 hours before the meeting was made. The motion was amended for $200. The motion passed unanimously.

8) The two track system was discussed for the

HOW BASIC CAN PROCESS RHEOLOGY BE?

J. R. A. Pearson
Department of Chemical Engineering
University of Cambridge

Text of an invited lecture to be given at the 1971 Fall Meeting of the Society of Rheology, 26-28 October, Princeton, N.J., U.S.A.

Synopsis:

This talk considers what a rheologist in the process industries does, can and should measure; how and how accurately he does or should do it.

An industrial rheologist studies the behaviour of materials under strain (usually large amplitude strain) in order to predict or explain (i) flow patterns in equipment and (ii) the physical state of the resulting output; he is usually interested in the interrelations between (i) and (ii). This involves the equations of motion and energy as well as rheological equations of state. Current emphasis on homogeneous 'memory' fluid models, admirable for some academic purposes, is only partially relevant for many industrial situations, including those of the polymer industry; in particular, a complete preoccupation with the measurement of difference of normal stresses in viscometric flow or dynamic viscosity in small amplitude disturbances is indefensible. Many materials exhibit gross physical changes during processing that are not reasonably covered by mathematical formulations that neglect microscopic behaviour.

The conclusion is that a detailed analysis, experimental and theoretical, of specific processes, including *all* the relevant factors, is the most profitable activity for industry. Rheologists can help with this as examples will show.

I was invited to discuss, in this talk, the relationship between rheological theories, rheological experiments and commercially important processes which depend upon the rheological properties of the material processed. In particular, I was asked to consider which in my view were the most useful measurements to make, what problems were involved, and what had so far been achieved in applying these measurements. I accepted the invitation because I think that there is still a need to point out the large gap that exists between the approaches and findings of pure rheologists on the one hand and the rheological problems of the process industries on the other. It is these latter which are the province of many applied rheologists.

I intend to persuade you, if I can, that industrial rheologists should direct most of their attention to direct investigation of industrial processes. The tendency to look for fundamental problems, though admirable in academics, and necessary for the long term development of any subject, is characteristic of too many workers supposedly applying existing knowledge, and is leading to a waste of effort which neither advances knowledge nor satisfies employers. The present need is for a pragmatic approach.

Practitioners of applied hydro- and aero-dynamics have had, over the years, many spectacular successes in explaining in detail the behaviour of water and air flows; as a result the disciplines attract excellent students, are well represented academically, and are well supported institutionally and industrially; they are now classical activities and have contributed in considerable measure to our present technologies. The numbers of workers involved are such that there is no sharp division between the pure and applied branches of the subjects.

Rheology as a discipline covers such a wide range of materials of differing rheological behaviour that it would be ridiculous to expect a similar situation to exist in general. However, it might have been hoped that in a limited number of fields of prime commercial importance, such as flow of polymer melts, concentrated polymer solutions or aqueous suspensions, greater progress would have been made. In practice, engineers and technologists have evolved processes that work, but usually with little knowledge or understanding of the kinematic and stress fields that arise. As a result processes are usually poorly controlled and satisfactory operating conditions difficult to predict. In an attempt to understand the flow processes involved, engineers turn for help to the rheologists and are usually disappointed. Why is this? Where does the fault lie? These are the questions that I would now like to consider.

A most important point, too often forgotten, is that both the processes and the materials are complex. Anybody wishing to understand and control a particular flow situation cannot expect in general to be provided with simple explanatory theories, calling only for a limited number of simple measurements that need be made to evaluate relevant parameters. The fact that a change of scale, a change of material, or an improvement in output and quality is imperative on commercial grounds, does not make its achievement any easier. As a result, workers have tended to adopt one of two policies: the first has been to retreat into a study of fundamental rheology; the second has been to place total faith in a strictly limited number of arbitrary concepts and measurements which force an apparent simplicity on the problem in hand. Each approach has its successes. The first is however an acceptance of temporary defeat in an applied sense; the latter depends for its success on individual intuitive skill. Unfortunately the two approaches have polarized and give little help to each other.

The majority of the papers on fluids accepted for presentation at this meeting come into the category of pure (rather than applied) rheology. By this I mean that they deal either with idealized materials (e.g. those obeying a simple equation of state) or idealized situations (such as viscometric flow or sinusoidal strain). Predictably, almost all are the result of research in universities or other academically inclined institutions. Collectively, they represent a definite advance along what is now a fairly well established set of paths, with an overwhelming inclination towards polymer melts and solutions. Only a few refer to what are problem areas in the process industries (e.g. die swell, melt flow instability, non-uniform extentional flow).

The next point to consider is how far attempts to characterize a real material rheologically can be successful and how useful such characterizations can be. A mathematical approach to fluid flow uncovers the basic simplicity of viscometric flows (yielding the viscometric functions) and small amplitude sinusoidal flows (leading to the dynamic viscosity functions). Further examples are provided by the constant stretch history flows achieved in Maxwell's orthogonal rheometer and the extensional rheometer and by the superposition of periodic and viscometric flows. For all these rheological behaviour is expressed in terms of a finite number of rheological functions (of the deformation tensor). Provided the kinematic flow fields can be achieved for long enough and the relevant components of the stress tensor can be measured, directly or indirectly, these functions can in principle be evaluated. In general, however, knowledge of these functions does not specify uniquely the behaviour to be expected in other flow conditions. Only when specific rheological equations of state (constitutive equations) have been proposed can such measurements be used to help specify a material completely. Unfortunately, real materials displaying pronounced elastic and non-Newtonian behaviour do not seem to be adequately described by simple equations of state. For example, stress relaxation and retardation seem to require characterization that is additional to the material functions mentioned above. This is in a sense a great disappointment, and profoundly important, because it means that, from our present continuum mechanical viewpoint, polymer melts and concentrated polymer solutions, even when apparently homogeneous, are very complex. It means that our hopes of extending classical Newtonian fluid mechanics by the use of a limited number of simple constitutive equations to cover most flows of importance have now largely faded. We are still a long way from being able to say that only determination and a large enough computer are needed for significant advances in prediction of flow patterns.

It must also be mentioned that the actual measurement of the various material functions mentioned above, although in principle possible, is not always easy to carry out. Certainly, it proves difficult to provide a single instrument (or small number of instruments) that will give accurate results for a large range of materials. Complications arise because (i) material time scales varying from less than a millisecond to a day or more are encountered (sometimes with the same material if it is subject to large temperature changes spanning a phase change) (ii) stresses of interest may range from 1 to 10^8 N/m^2 (iii) deformation rates may vary from 10^{-4} to 10^3 sec^{-1}. Thus (1) Purely mechanical difficulties arise in instrument design if sensitivity has to be balanced against robustness and this is usually the case. (2) Temperature control problems become severe if the material under investigation is very viscous and relatively large deformation rates are involved: the heat that is generated within the material leads to significant temperature gradients, which complicate the interpretation of results. (3) It is always difficult to achieve sufficiently closely the flow patterns (i.e. deformation histories) to which theory refers. This problem is complicated by the fact that strong elastic or non-Newtonian forces can lead to secondary flows that cause more than slight inaccuracies: the regions in which departure from the desired flow pattern occurs can thus become dominant rather than insignificant. (4) Unless the flow pattern is both uniform and steady (a situation that cannot in practice be achieved in an instrument of finite size) the forces measured are not direct multiples of the desired functions; in most cases they involve integration over a range of deformation rates—the range that arises in any experiment within the apparatus—and so numerical differentiation is needed to extract the required rheological functions. This introduces further inaccuracies.

Suppose, however, that we can make accurate observations and so determine a wide range of material functions. How far can these results be used predictively? Let us consider an obvious example: if we have made observations on viscometric flows, then we can predict the stresses that arise in other viscometric flows. Thus from a knowledge of the torque needed to achieve rotary flow in a Couette (concentric cylinder) viscometer at various rates of rotation, we can determine what flows will arise if an axial pressure gradient is imposed also in the same apparatus—provided of course that entry and exit effects can be neglected. (This is the case of helical flow.) By use of the lubrication approximation, we can predict approximately the flow in shallow closed channels of slowly varying depth. Indeed for highly shear sensitive and relatively inelastic fluids, these methods have been very useful. But it should be noted that only the viscosity function is important in these analyses. The two normal stress difference functions enter only passively into the analysis; the stress field due to them is not supposed to affect the flow pattern, and their only effect is to change the normal forces on the retaining walls of the channel. Unless these forces are significant—and they can only be so in general if the normal stress differences are *large* compared with the viscosity—then the normal stress differences, so difficult to measure, are not of engineering importance. If they are important, then the arguments used to interpret the relatively complex boundary value problem in terms of viscometric flow break down, and so no application is possible. To take a second example, knowledge of the dynamic viscosity function can be used directly in studying the propagation of shear waves through an elastic fluid. Thus inertial effects can be added to purely rheological ones to provide a significant predictive result. A third example is provided by the class of pure shear (or extensional) flows. Even some of the simplest constitutive equations predict rather unusual behaviour in pure axisymmetric extension. For example the Maxwell model (for a uniformly extending filament) predicts a singularity in tensile stress as a function of rate of extension. Others, however, predict nothing unusual. This has suggested the measurement of extensional viscosity (only a well defined function for a fluid subjected to uniform and steady extensional flow), and indeed it has been possible to do so for very viscous materials. For less viscous materials, an approximate realization of the necessary flow field has been achieved from which estimates of the extensional viscosity have been obtained. It has been found that in all cases, the ratio of extensional to simple shear viscosity has increased with deformation rate—for a Newtonian fluid the ratio is constant at 3. In cases of relatively inviscid solutions the ratio can rise by 2 or more factors of 10; this leads to a very pronounced effect in changing the pattern of converging or sink-like flows so that high rates of extension are not achieved. As yet, the accuracy of the measurements made and the range of extension rates studied is limited. Nevertheless the results indicate a large increase in stress for rapid extensional flows. Several workers have tried to apply these observations to predict or understand the behaviour of a spinning threadline (a molten filament). Here inertia, drag and surface tension forces can be relevant, and so if the relevant rheological behaviour of the material can be studied under simpler conditions, a significant application of these results could be made. Results so far indicate that the rates of change of extension rate in the threadline are themselves important in determining the threadline tension; thus, the spinning threadline is now treated as a feasible experimental flow capable of yielding rheological information, rather than as a means of testing the applicability of theoretical predictions.

If we look more widely at the flows that arise in practice, we find that significant departures from simple shear or simple extension arise. These mean that the deformation histories of individual fluid elements are not easily described: within the time scale of the fluid, the fluid elements are subjected to varying deformation rates (both in type and magnitude). In a crude sense relaxation and retardation effects are necessarily involved. Although precise experiments can be carried out to measure stress relaxation after a long period of continuous uniform shear, or stress retardation and overshoot after instantaneous application of uniform shear, these in themselves cannot be simply generalized to cover the three-dimensional histories that arise in practice, for example in non-uniform channel flows. In the case of primarily extensional flows the extent to which a small component of vorticity will affect the observed large increase in extensional viscosity has not been investigated. Thus, for example, we are left in considerable doubt about the precise behaviour of elastic fluids in rapidly converging (as in the entrance to die lips or to spinnarets) or diverging flow (as in the die swell region beyond a die or spinnaret). I have avoided here discussion of the relationships between axisymmetric and two-dimensional extension—or, as some would put it, of the role of the 'third invariant' of the rate of deformation tensor in the rheological specification of a material. Observations so far made suggest that significant differences can occur between materials.

In addition, we are sometimes faced with the unexpected occurrence of secondary flows or flow instability, in which the imposed symmetry of the boundary is not matched by the field. Thus uniaxial flow in a straight pipe of elliptic cross-section, possible with a Newtonian fluid, is not possible with certain non-linear fluids. This can be regarded as caused by the influence of the differing (unbalanced) normal stresses that would arise if a uniaxial flow were instantaneously achieved. Also, we find that two-dimensional rectilinear flow in the channel formed between two long and wide parallel plates placed close together can develop roll vortices, above certain flow rates, that are analogous to the 'Taylor vortices' that arise in concentric cylindrical viscometers above a certain Reynolds (Taylor) number. With hightly elastic fluids the instability leading to secondary flow is due, not to inertia, but to normal forces. These effects are probably related to many of the observations on elastic turbulence (melt fracture), but the factors leading to 'flow defects' are still far from well understood.

So much for kinematics and the possible prediction of flow fields. Let us now turn to the relationship between rheological measurement, rheological theories and the initial and final properties of processed materials. The key factor here is structure. Let us take an example: the utility of many rigid plastics is critically dependent on their crystalline morphology. Recent experiments have demonstrated conclusively that this morphology is profoundly affected by both stress and temperature conditions at the time of crystallization. In the case of solutions, rapid elongation or shear has been shown to increase the rate of crystallization to such an extent that it can completely alter the nature of the process. In the case of melts, we find firstly that the actual crystalline melt point can be significantly changed (differences of the order of 10°C) by the absolute isotropic pressures met in processing equipment, particularly injection moulding, secondly that the rate of cooling determines crystallite size and lastly that molecular orientation caused by shear during the final stages of cooling leads to frozen-in orientation in the solid article. Moreover, these variations in material conditions lead to variations in rheology, and so can lead to critically important interactive effects during the final stages of cooling. Although in principle these effects can be included in formal theories, none so far advanced takes explicit note of them.

In practice the control of heat generation within and of heat flow into and out of the material being processed is regarded as the most important factor in the technology of plastics processing. So much so that many technologists tend to regard rheological behaviour as merely an interesting but tedious by-product of making materials from high polymers. They will admit that only controlled deformation will yield the products they need. However because they understand the deformation processes less thoroughly than those of heat transfer on the one hand and chemical structure on the other, they have tended to seek changes in the resultant product more by control of polymer structure and temperature history than by control of deformation history. There are, of course, exceptions to this general statement, though even the exceptions make it clear that control of rheological factors is largely indirect. At a very elementary level, it is galling for the pure rheologist to find that the Brabender Plastograph is still favoured by many practical men to characterize a new P.V.C. or rubbery material—galling to the purist because what goes on in such a 'measuring' device is too complex for him to unravel, being at once unsteady, non-uniform, temperature dependent and liable to involve chemical change; yet it is attractive to the practical man just because it does combine those several factors, which he knows are simultaneously relevant in processing. Moreover, he can point out with some justice that the purist is still a long way from solving some of the problems arising from the factors taken separately, let alone in combination.

Mention of structure leads us to multi-phase and disperse systems. Here we meet another present restriction of the a priori mathematical approach, which so far has tended to consider homogeneous systems. Many disperse systems cannot be regarded as homogeneous: not only are the length scales of individual particles not sufficiently small with respect to flow length scales, but also particle migration effects caused by flow can make the material non-uniform, i.e. the ratio of components can vary within the flowing material. Add to this the possibility that micro-structure (such as degree of agglomeration) can be irreversibly affected by thermal or shear history, and we have a very complicated situation indeed. The examples one can choose to illustrate this comment are as diverse as the systems selected. The flow of blood down arteries and capillaries can only be explained in terms of the movement of individual (and deformable) red blood cells; gross measurements of viscometric functions are totally, and not unexpectedly, inadequate to predict such behaviour. Dry blend P.V.C. powder fed to a single screw extruder and formed into pipe retains in practice, as can be verified by viewing microscopically, a granular structure that is inherited from the polymerization vessel. Thus its behaviour in the extruder is never that governed by the rheology of a 'pure' P.V.C. melt; indeed the more carefully the dedicated rheologist purifies his samples of material to obtain fundamental parameters to characterie P.V.C., the further he may get from the really important processing factors. The industrial rheologist who avoids this by starting with P.V.C. powder as supplied to the extruder finds to his chagrin that its rheological behaviour on its first pass through a capillary rheometer may differ significantly from that on its second, even though in both it has been at a controlled temperature, above the 'melting' point.

This brings me back to the question I used as a title: How basic can process rheology be? You will have guessed my answer by now: at the present state of knowledge, only slightly so or not at all. Nor should it be otherwise on either scientific or technological grounds, and I hope to explain why. This is not meant as a recommendation to unalloyed empiricism: on the contrary, it is a plea to those concerned with processing that rheological considerations cannot usefully be separated from other factors; it is an acknowledgement that the coupling between rheological behaviour, heat transfer and chemical or physical state is close. For this reason I see the main concern of an applied rheologist in industry as the process itself; at this level, his work becomes specific, not fundamental. He should concern himself with observing, and measuring, velocity, pressure and temperature fields on and within the material being processed. If he can simultaneously measure the local material structure or state, this too should be done. If he must theorize, let him theorize about the process he is observing, let him build a mathematical model based not only on rheological equations of state, but also on the conservation equations—of mass, momentum and energy—and any kinetic equations of material change that are relevant. In general such systems of equations will be far too complex to handle; his skill will therefore lie in selecting the correct approximation to employ, whether geometrical or physical. Some of his simplifications can be based right from the start on the size of relevant dimensionless quantities; for example, if all Reynolds numbers are small, then inertia can be neglected; if all Deborah numbers are small, then elasticoviscous effects can be dealt with in terms of the local deformation field; if Péclet numbers are very high, conduction effects can either be neglected altogether or else confined to directions normal to stream lines. Some can be based on his direct observations; an example of this is provided by the entry flow to a sharp edged die, where an essentially irrotational flow arises for elastic fluids, leaving trapped vortices of recirculating fluid in the corners. Some can be introduced a posteriori as a result of detailed numerical calculations. In short, let him adopt the traditional approach of an inquiring engineer.[1]

What I have suggested is not without its own weaknesses and difficulties: indeed, I must in fairness show what benefits might follow from its adoption. The principal advantage to be gained is that of bridging the gap between present pure rheologists and present process technologists. In doing this, a great deal of interesting and important information on the behaviour of real materials in bulk should become available to academic workers in sufficiently detailed form for them to make use of it. One of the difficulties at present is that predictions for process flows, however speculative, based on existing knowledge cannot in most cases be compared with precise measurements on processes, because the latter do not exist. A better supply of detailed data on current processes would encourage a more useful selection of 'boundary-value problems' for solution.

Another, rather indirect, advantage might result. Within industry, it is often the case that research is carried out on plant or apparatus separate from production or even development equipment. Technologists concerned with the latter are expected to adopt a different approach from full-time specialists like rheologists; so the young graduate rheologist, often well grounded in a range of disciplines (typically he may be a Ph.D. in chemical engineering) is put to work on topics that are neither immediately relevant nor of long-term importance. Often he deliberately turns away from the full process problem to study, with suitable objectivity, one aspect of it, as much as anything on grounds of scientific respectability, then, all too often, he is withdrawn from that almost closed environment, is required to adopt a more 'commercial' attitude, and suffers a form of mental 'conversion' which somehow manages to perpetuate the gap between learning and practice. If, instead, this same young graduate could be allowed to investigate actual production processes, I believe that significant improvements in productivity and quality could be attained more easily and cheaply than at present, while the transition from investigator to manager could be less traumatically induced.

I do not expect to have convinced all my audience of my thesis, though I hope that I shall not be misinterpreted. I do not wish to imply that pure rheologists are following the wrong path: far from it. I would however echo the view that perhaps more time should be spent in studying what has already been discovered than in trying to add to the paper contributions on the subject. Nor do I wish to imply that nowhere is science being usefully applied to processing problems; if it were not for several outstanding examples of cooperative investigations spanning many disciplines, undertaken in the main by large companies, then I would feel less confident in recommending such an approach here. But more than anything, I think that studying real problems is more satisfying than inventing paper ones, and that working on a problem that is of direct interest to one's colleagues brings the sort of stimulus and recognition that most of us need and appreciate.

REFERENCE

1. M. A. Biot. *Appl. Mech. Rev. 16*, 89 (1963).

Transactions and a motion to make the page charges honoring at 70% and not to apply the concept to papers already accepted. The motion was seconded. The motion passed with 6 voting yes, 1 abstaining. Interscience will do the sorting into two tracks.

9) E. Collins reported that to do a good rheological survey, i.e., to poll all the rheologists and tabulate the data would cost $1000. After discussion, it was decided this is too expensive. A small survey of Society members will be undertaken by mailing the questionnaire with a Bulletin.

10) A motion was passed to hold the regular Winter Meeting in 1972 jointly with the Division of High Polymer Physics if possible.

11) A motion was passed to delay the official "Annual Meeting of 1972" until January 1973 so that it should not be too soon after the Sixth International Congress of Rheology which will meet in September 1972. The invitation to hold this meeting in Canada was accepted.

12) The Annual Meeting of 1973 will be held in October 1973 at a site to be selected after consultation with various members who have issued invitations in the past.

13) The meeting was adjourned at 3:30 p.m.

Respectfully submitted,
John C. Miller
Secretary

SOCIETY OF RHEOLOGY

Report of the Secretary — 1970

Publication Charges:

It was reported last year that the page charge collection has fallen to about 40% of the total number of pages. The situation has not improved in Volume 13 and 14 where the total number of pages was 802 with only 354 pages paid. This change from 74% collection of charges to 40-50% is a serious drain on our finances.

Membership:

The membership has increased only slightly since last year to a total of 789. Our increase in membership from 1966, 750 members. This represents an increase of 6% over the past 4 years. A new membership chairman has been appointed — Mr. Glenn E. Fulmer.

Publications:

Three issues of the Rheology Bulletin were published and sent to the membership. Volume 14 of the Transactions of the Society of Rheology was published in four parts.

Meetings:

Two technical meetings were held in 1970. One at the University of California, February 2-4. The program chairman was Prof. N. Tschoegl. The second meeting was held at Princeton University October 26-28. The program chairman was Dr. A. P. Metzger and the arrangements were made by Prof. W. R. Schowalter.

The Executive Committee met twice during the year, in Pittsburgh on March 9, 1970 and at Princeton on October 25.

Relations with American Institute of Physics:

All mailings, dues, collections, and accounting funds were made by AIP.

The American Institute of Physics has reached a financial crisis in supporting the Society-Member programs. Some of these programs are

1) History of Physics
2) Public Relations
3) Society Services
4) Physics Today
5) Education and Manpower

The AIP estimates these programs cost $8.50 per member and presently all Societies pay $1.00 per member. The difference has been made up in the past by NSF or publication revenues from AIP Journals. To review the situation and make recommendations to the Governing Board of AIP, a committee which consists of one member from every society has been appointed. The Society of Rheology representative is Dr. R. S. Marvin.

Acknowledgments:

The Secretary is grateful for the cooperation of the Society officers, committees, and the American Institute of Physics.

The Secretary is grateful for minor services and expenses supplied by the Union Carbide Corporation necessary to the performance of his duties.

Respectfully submitted,
John C. Miller
Secretary

SIXTH INTERNATIONAL CONGRESS ON RHEOLOGY

The 1972 International Congress will be held in Lyon, France, September 4-9. A charter flight will be organized by R. Coulehan.

The first circular for the Sixth International Congress on Rheology to be held at Lyon, France, September 4-8, 1972, has been sent separately to all members. The second circular will be sent directly to all who request it from the Organizing Secretary, Dr. C. Smadja, Boîte Postale no 1, 69 - Lyon-Mouche, France, before November 1, 1971. In addition to the program outlined in the first circular, a special symposium on biorheology is being planned by Dr. A. L. Copley, President of the International Society of Biorheology, and and others, which will be designated as the First International Congress on Biorheology. An instrument exhibit may be included. Dr. Smadja would welcome inquiries and suggestions about possible participants in such an exhibit.

Titles and abstracts should be submitted before March 1, 1972.

The Czechoslovakian rheologists expect to hold a conference on September 11-14 (after the 6th Congress) in Prague covering general principles of rheology. This conference will be an interdisciplinary discussion of flow, viscoelasticity, plasticity and fracture, with emphasis on theoretical aspects.

AMERICAN INSTITUTE OF PHYSICS INCORPORATED for SOCIETY OF RHEOLOGY

Statement of Receipts and Disbursements
Year Ended December 31, 1970

Balance in Account — January 1, 1970		$15,942.00
RECEIPTS (January 1 - December 31, 1970)		
Dues Collections:		9,539.03
Miscellaneous Income:		
Fall Meeting, 1970 - Union Carbide Contribution	$ 200.00	
Interest on U.S. Government Bond*	90.00	
Winter Meeting, 1970	360.92	650.92
Total Receipts		$26,131.95
DISBURSEMENTS (January 1 - December 31, 1970)		
Charge for Dues Billing and Collection	$ 450.44	
Maintenance of Member Record File	650.92	
Financial Handling Charge - 1970	65.01	
Member Society Dues - 1970	775.00	
Spring Bulletin:		
Printing Expense	188.00	
Ballot Mailing:		
Postage	1.94	
Winter Meeting	728.14	
Fall Meeting	611.66	
August Bulletin	219.25	
Editorial Expenses	1,200.00	
Communications, Administrative, Brochure, and Directory	517.32	
Transactions - Subscription Expense	1,952.13	
Transactions (Schedule A)	2,666.31	
Total Disbursements		10,026.12
Balance in Account, December 31, 1970		$16,105.83

TRANSACTIONS OF THE SOCIETY OF RHEOLOGY

Statement of Income and Expense (Schedule A)
Year Ended December 31, 1970

INCOME	
Publication Charges (Volume 13 #4, 14 #1-4)	$ 4,155.00
Reprint Sales (Volume 13 #4, 14 #1-4)	1,321.71
Total Income	$ 5,476.71
EXPENSE	
Publishing Expense	$ 6,505.98
Printing Reprints (Wiley)	1,321.71
Order Handling Charge	315.33
Total Expense	$ 8,143.02
Net Income or (Expense)	($2,666.31)

* Bingham Fund: $1,000.00 U.S. Government Bond (Reinvested) 6% - Due May 15, 1975.

April 15, 1971 R. E. Coulehan