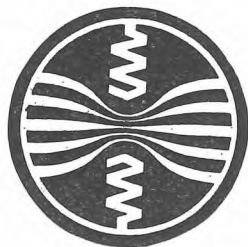


BULLETIN



BRITISH SOCIETY OF RHEOLOGY

1970, No. 4, Vol. 13

CONTENTS

	Page
Foreword	89
Officers and Council	90
Victorian Branch 1969-70 Committee	90
President's Address	91
Reports:	
Bulletin	99
Rheology Abstracts	99
Hon. Treasurer	101
Membership Secretary	104
Research Committee	104
Working Party on Publications	104
B.S.R. Autumn Conference 1970	106
Victorian Branch	111
Dr. G. W. Scott-Blair	113
Special Notice to Members—Membership Secretary	115
Cahiers du Groupe Français de Rhéologie	115
B.S.R. Autumn Conference 1971	115

Hon. Editor:

JOHN HARRIS,
Schools of Chemical Engineering,
The University,
Bradford,
Yorks. U.K.



Contents continued

Society of Rheology (U.S.A.)	...	...	...	...	...	116
Symposium on Non-Newtonian Technology	...	...	...	...	...	116
Course on Plastics Rheology	...	...	...	...	...	117
Chemeca '70—Abstract of Programme	...	...	...	...	...	118
Announcement	...	...	...	...	...	121
Notice from the Honorary Secretary	...	...	...	...	...	121
Appendix:						
Iterative Numerical Methods for Some Integral Equations arising in Rheology	...	...	...	...	...	122
Computer Programme Catalogue Abstract	...	...	...	...	...	133
Diary	...	...	...	...	...	135

FOREWORD

With this issue of the Bulletin we have the pleasure of introducing Professor J. Lamb of Glasgow University as the President of our Society for the 1970-72 term of office. In this, as in most other aspects of life, one rarely makes a gain without an accompanying loss and here we recall the expert handling of many council meetings by our immediate past President, Dr. L. Grunberg of the National Engineering Laboratory, whose parting address at the recent Annual B.S.R. Conference at Shrivenham is printed elsewhere in this issue. Dr. Grunberg's long experience and wide contacts are a valuable asset in throwing problems into perspective and it is to be hoped that the Society will not entirely lose the benefit of his judgement.

The new President is already well known in scientific circles for his contributions in the field of high-frequency mechanical response of liquids involving both development of experimental technique and elucidation of the structure of materials. In the immediate future there are several important features which will bear on the development of rheology in this country and which will benefit from imaginative thinking.

COUNCIL 1970-71

President: PROFESSOR J. LAMB, Department of Electrical Engineering,
University of Glasgow.

Hon. Secretary: DR. K. M. BEAZLEY, English China Clays, St. Austell.

Hon. Treasurer: MR. R. W. WHORLOW, Department of Physics,
University of Surrey.

Membership Secretary: MR. R. R. ADDIS, 7 Dale Gardens, Little
Sandhurst, Nr. Camberley, Surrey.

Abstracts Editor: MR. A. EVANS, Department of Surgery, University
of Newcastle-upon-Tyne.

Bulletin Editor: DR. J. HARRIS, Schools of Chemical Engineering,
The University, Bradford.

Ordinary Members

DR. J. M. HOBBS, MR. J. F. HUTTON, DR. B. S. NEUMANN, DR.
J. R. A. PEARSON, MR. A. PLEASE, DR. K. WALTERS.

1970-71 COUNCIL, VICTORIAN BRANCH (AUSTRALIA)

President: MR. O. DELATYCKI, Department of Industrial Science,
University of Melbourne.

Hon. Secretary: DR. J. M. STEARNE, ICIANZ Ltd., Victoria 3032.

Hon. Treasurer: DR. E. J. DICKINSON, Australian Road Research
Board, Victoria 3101.

Editor (Abstracts): DR. R. FOX, ICIANZ Ltd., Victoria 3032.

Committee: MR. W. H. COPLEY, MR. J. D. GIBSON, MR. K. MARTIN.

PRESIDENT'S ADDRESS

WHITHER INDUSTRIAL RHEOLOGY?

Introductory Address by the President to Conference on Rheology in Industry

Shrivenham, September 1970

In many learned societies the President addresses the members much in the manner of the Queen's speech surveying the state of the society's interests and indicating how he would lead the society out of the wilderness into a promised land. In giving this address to you as your outgoing president I am relieved of the need to make promises which may be difficult to keep. I will leave this to my able and distinguished successor who, as is your privilege, you will elect at the Annual General Meeting tonight.

We are living through a period of searching enquiry into the purpose and usefulness of scientific and technological research and I thought it appropriate to conduct a brief enquiry at this occasion. I will not go as far as digging up the seeds that have been sown to ascertain whether or not they have germinated. I believe that in the case of rheology growth is definitely showing above ground. The problem is more which branches should be encouraged to grow and which are to be pruned in order to achieve the greatest benefit for society at large. At the end of my talk some of you may think that I have been unduly critical. I, however, feel that a healthy dose of self criticism is often the only way in which scientists can avoid self satisfaction and complacency.

At the outset it is necessary to give some thought to what rheology really is. Definitions found in standard dictionaries are not wholly satisfactory. Rheology is said to be the science or study of flow and deformation of matter. If one examines what practising rheologists in the main do, one finds that only a minor proportion can be found in ivory towers defining general principles and systematising critically examined observations. Most of us must remain content to find solutions for particular problems which only exceptionally can be derived from general principles and more often than not depend on observations which make a higher demand on intuition than on intellect. My experience of the situation dates back some forty years when as a young apprentice student in pharmacy I had to acquire the skill of judging the consistency of mixes for making pills or other pharmaceutical preparations. Even later when I became concerned with the flow characteristics of petrol gels, inks for ball-point pens or even with viscosity of pure liquids an intuitive approach to the interpretation of observations often yielded better results than attempts to explain fully and critically what was happening.

One has to enquire seriously whether rheology is a craft, a science or a technology and where the origins of our subject lay. I cannot do better than refer to what I regard to be the most moving passage, perhaps the only moving passage, in the literature of rheology. This is the dedication which Dr. Scott-Blair, whom we all look upon as the father of our Society, wrote to his Survey of General and Applied Rheology. He dedicates his book to Bill, the original rheologist, I quote: "When they want to know what to do next they send for Bill. Bill squeezes the stuff in his fingers, sniffs it, holds it to his ear and squeezes it again. Then he looks wise and says 'O.K.' or 'Leave it for another ten minutes'." Dr. Scott-Blair then pleads with old Bill not to oppose the intrusion of science. In the course of my career I met Bill in several forms and guises. One instance which I recall hapened during the last war when the supply of tallow became scarce and a firm of cotton rope manufacturers was in real difficulties about this. The lubricant used with the ropes was based on tallow and they had an old Bill, whose name was actually John, who knew exactly how to cook the mixture of tallow, graphite and other ingredients in order to produce the right mix. He operated in a dingy shed in a backyard despised and forgotten by management until he was unable to supply the lubricant on which production depended. The laboratory in which I was working was called upon to find a substitute which matched the lubricant based on tallow. As true rheologists we made stress-strain measurements on the original product and on mixes of ingredients (mainly petroleum products) which were easily obtainable. We were successful in matching the properties of the tallow-based product and our friend John accepted our recipe with relish. He seemed highly flattered by the notice that his activities had received and that the scientists had had so much trouble in matching his concoction. Except for the fact that we used measurements of one kind or another we felt very much like old John of having achieved the result without knowing why. We had relied on the tools of our trade, namely rheological instruments whilst old John had used his physical senses. What we had in common was that neither of us knew why we had been successful. Now an answer to the question why, is basic to the whole concept of a science. The main transition which is and has been important in rheology is that from craft to technology and not from craft to science. If only our archeological records were complete this development should be traceable to the beginnings of the human race. Early man used his physical senses to judge the consistency of his mix of clay and water which he could shape with his hands into pottery or sacred figurines. Later he invented the potter's wheel to aid him in shaping vessels and at some stage he must have used a piece of wood or stone to prod the mix in order to decide on its consistency. Similar development occurred in judging the ripeness of milk products, the flow characteristic of printing inks, the lubricating performance of greases

and so on. Having then arrived at the present time one can well ask in which way old Bills' and Ph.Ds' in the laboratories differ in their contribution to society. I believe it is mainly in the time required to arrive at a useful result. Old Bill needed the experience of decades, centuries or perhaps millennia, whilst modern rheologists compress this experience into months or years.

Having achieved this real and historical perspective I need to turn to rheology as a science. This implies in the first instance ascertaining unambiguously that certain processes or phenomena are happening in carefully controlled circumstances and interpreting in a rational way why they are happening. Some progress has been made, but the degree of perfection is still very limited. In 1961 when we in the National Engineering Laboratory gathered the rheological work on liquids into Fluids Group it was necessary to devise a strategic plan for our activities in a situation in which we found ourselves in D.S.I.R. as between industry and the universities. For various reasons elastico viscous liquids appeared to be the most attractive and useful field. Examination of the situation showed that whilst a considerable amount of theoretical and academic research was being done it had very little impact on the legitimate successors of old Bill with university degrees in industry who had to solve practical problems within limited time scales.

We decided to take a path which differed materially from that normally pursued by research workers. Usually one is faced with a geometrical configuration of some kind in which the flow of a liquid with particular properties takes place. Using theory and/or experiment the situation is described by the rheologist. The problem which we set ourselves was to establish to what extent the rheologist has intuitively to make a choice in interpreting theory in order to obtain agreement with experiment. In the case of Newtonian liquids we knew that the choice to be made is very limited and confined to the approximations involved in solving the equations of state, and those of motion and of continuity known as the Navier-Stokes equations. The degree of empiricism is very small indeed and a single material constant, viscosity derived from one flow situation can be used to describe other flow situations.

We found that the same happy state of affairs did not exist for liquids which are elastic as well as viscous. Whilst it is true that in simple shearing motion the properties of the material can be described by three functions of the rate of shear, these functions however would be different and generally insufficient if the material should be subjected to a different rheological history. This difficulty manifests itself when it is attempted to set up flow equations for particular situations and demands that the right equation of state be chosen to achieve agreement with real behaviour. The mathematical difficulties impose their own restrictions and ultimately the degree of empiricism

necessary to achieve agreement between the material constants assumed to represent the properties of the fluid, i.e., the equation of state chosen and the formulation of the flow problem becomes formidable. Experience and intuition, therefore, play an important role in solving practical and real problems. Although the investigations at N.E.L. were confined to elastico-viscous fluids the understanding of other non-Newtonian fluids is also imperfect.

Both rheologists and chemical engineers have recently become concerned about the wide gap that exists between the results of theoretical research and their application in industry. Reports have been issued by the Research Committee of the A.I.Chem.E. and by a Joint Working Party of the Research Committees of the British Society of Rheology and the I.Chem.E. These reports pinpoint only some of the problems.

The economic importance of the industries manufacturing and using non-Newtonian materials is tremendous. I will not quote the value of the products as the figures normally transcend the comprehension of those not engaged in econometric studies. Excluding the metallurgical industries and confining oneself to other technological areas in which non-Newtonian fluid mechanics is important one can compile a formidable list:

- The production and utilisation of polymers, resins and elastomers

- The production of synthetic fibres

- The production and utilisation of paints and varnishes

- Petroleum technology (lubricating oils, greases and drilling mud)

- Paper technology

- Mineral processing

- Concrete technology

- Food processing and manufacture (milk and cereal products, chocolate, butter, margarine and so on).

One could go on adding to the list, but it is clear if the Deity suddenly decreed the abrogation of "panta rhei" life on earth would become somewhat difficult.

One of the important problems in industrial rheology is product characterisation. This is required for the purposes of quality control and specification of usage. I will try and trace for you the development or perhaps the lack of development of one particular test, namely that of the penetration characteristics of greases. Greases as you know are in the main mixtures of soap and lubricating oils. In the old Lubrication Division at N.E.L. we established at least to our own satisfaction that the soap fibres did not contribute to the lubrication process itself. Rheodestruction of the fibres did not diminish the lubrication of surfaces provided the grease was available at critical points and this depended solely on the flow properties of the grease.

One would expect that the characterisation of the flow properties of a product of such industrial and economic importance would be based on sound and clearly interpretable rheological principles.

The earliest method which in some fashion is still with us dates possibly from the First World War and originated in the U.S.A. A composite cone, 150g in weight, with an upper cone angle of 90° and a lower cone angle of 30° was allowed to sink into a 4lb. sample of grease for a period of 5s and the depth of penetration was measured. The complex geometry of the cone, which it was thought, would make the instrument usable for thick and thin greases, made it impossible to relate it conclusively to any rheological quantity, such as yield stress or apparent viscosity. The numerical values were entirely empirical.

The clumsiness of the instrument and the large quantity of sample led to several attempts to miniaturise the instrument. Results had of course to correlate with the original test procedure which had established itself in commerce. Attempts were made to correlate penetration with apparent viscosity with some very uncertain consequences. All this happened in the U.S.A. and not until 1950 did European workers try to improve the situation. Using a 90° cone a Cone Resistance Value was defined as effective load divided by the cross sectional area of the cone at the grease surface. Apart from simplifying the geometry, workers at Thornton were able to correlate grease performance such as slumping in bearings and dispensing with the cone resistance values of greases. A value of the yield stress could be calculated by assuming either complete slippage or the absence of slip between material and the penetrating surface.

There followed a long battle in committees concerned with standardisation. Nearly twenty years after the improvement had been suggested it has not yet been adopted in standards. This example illustrates the danger that is inherent in empiricism. Once a certain procedure and its interpretation becomes established and the basis of commercial dealings it becomes impossible to dislodge and replace it with something more acceptable in scientific terms.

The industrial rheologist is of course concerned with mass and energy transfer problems, he must mix the ingredients, change their nature, transport them and shape them into the final products. The Institution of Chemical Engineers has through their Industrial Research Fellow Scheme provided excellent summaries of the state of the art in various areas. On mixing for instance it has been suggested that through an analytical approach one might be able to correlate the shape of the mixer, and the velocity distribution with the flow pattern which deforms and mixes the material. There are obstacles to such an approach as it can at present deal only with problems in which the velocity and temperature profiles are fully developed. Only in rare circumstances does this obtain and this

idealised treatment at best aids empiricism, but does not eliminate it. The only flow equation which is simple enough to be generally used in design equations is the "power law" relating the shear stress to the rate of shear raised to some experimentally determined index. Whilst considering challenging problems in chemical engineering one may well ask why two-phase flow situations, e.g., the simultaneous flow of liquid and gas have not been considered as falling within the sphere of rheology. Rheology Abstracts almost entirely ignore the literature on two-phase flow problems and workers in the field do not regard themselves as rheologists. As two-phase matter is not a continuum it cannot be described in terms of continuum mechanics. The preoccupation of rheologists with continuum mechanics has kept this challenging and important subject outside the Society's activities.

In many aspects of process engineering the "unit operation" concept has led to considerable progress in providing designers with sound principles. This basically depends on breaking up a complex process into stages which are capable of being described from a truly scientific point of view. When this is possible the solutions become independent of the material being processed. The view has recently been expressed that this concept should be applied to non-Newtonian technology. I believe that the suggestion whilst interesting is not practical. In all situations in which the unit operation approach has been successful the transport and thermodynamic properties of the fluids involved could be universally and unambiguously defined by experiment, prediction or theory. The latter condition does not obtain at present for non-Newtonian materials. Thus whilst it would be useful to organise process engineering problems from the unit operations point of view the solutions will be of limited usefulness until it becomes possible to describe the behaviour of non-Newtonian fluids in an unambiguous and universal manner.

The key problem of advancing industrial rheology is thus to find more adequate methods of describing materials and their properties. Leaving aside the empirical approach used in specific situations almost the whole of our effort is devoted to trying to define flow behaviour from the point of view of the mechanics of continua. This seems to me quite illogical. There can be little doubt that the complexity of behaviour of non-Newtonian materials derives from particle interactions, from structural breakdown or build-up and indeed from the properties of individual particles. Nobody, I think, will deny that the elasticity of elastico-viscous fluids such as poly-isobutylene solutions depends on the flexibility of the solute molecules. I will give you an example which recently roused my interest. We have all been intrigued by the phenomenon of drag-reduction in turbulent fluid friction. The addition of Polyox reduces the friction factor and changes the behaviour of the solvent without any great change in the viscosity of the solution. Recently I saw a letter in "Nature" which seems to show that the shape of the molecular coil was the controlling factor.

D.N.A. was used in the experiments and it is interesting that it acts as a drag-reducing agent. Because of its great significance in biology the structure and behaviour of D.N.A. has been widely investigated and described in the scientific as well as in the profane literature. Its double helix not only provided the opportunity for winning Nobel Prizes but seems to suggest a connection between structure and drag reduction. In solutions of intermediate pH in which the helical structure exists drag reduction was observed. The phenomenon disappeared at low and high pH when as is known D.N.A. becomes "denatured" and loses its helical structure. These observations whilst not fully explaining drag reduction establish a connection between a rheological phenomenon and the structure of the particles responsible for it. I believe that a change of direction of rheological research is required. Further endeavour to create continuum models of increasing complexity or to deploy more sophisticated mathematical tools is not likely to advance our subject materially. What is required is the use of advanced experimental techniques in the study of the molecules or molecular aggregates which are responsible for the non-Newtonian behaviour.

I can now shift the argument on to a personal plane. Without anticipating tonight's election of officers of the Society I can hopefully state that my successor in office will be Professor John Lamb. Most of you will be familiar with his extensive researches on the use of acoustic techniques to the study of molecular behaviour. It is this type of research which eventually will bring us to a closer understanding of the rheological behaviour of materials. Physics has provided innumerable tools for this purpose and they should be used. I reached this conclusion many years ago and we at N.E.L. have provided support for Professor Lamb's work for about a decade. In the scientific area my plea therefore is for less theoretical model building and applied mathematics and for more physics applied to the particulate nature of the materials which we are investigating. I do not wish to imply that the technological front should remain quiescent. Although the time is not yet ripe for a unit operations approach there is much to be learned experimentally about what happens in a piece of industrial equipment. We at N.E.L. are reorientating our rheological research towards hardware and away from pure description of materials. Detailed rather than overall performance data of pumps, heat exchangers and flowmeters is our objective and sophisticated experimental techniques will be used. I hope that others will follow Professor Lamb's and our examples.

I believe I have performed a rather curious feat in delivering a lecture on rheology without using a single mathematical expression and without trying to justify empirical experience. This entitles you and I to some light relief. This I will provide by returning to the start of my talk and by showing you the only slide which I have brought along with me. It shows the results of the endeavours of a



Fig. 1. THE VENUS OF WILLENDORF

paleolithic rheologist who hammered away at a piece of material to produce the outline of a female figure known as The Venus of Willendorf (figure 1). I offer no apologies for showing the results of a study in fracture as by decision of Council this falls within the interests of the Society. I am sure you will not fail to notice the distinct difference between the shape of the figurine and the splendid examples of mini, midi or maxi skirted figures which we often see around us and which nature has shaped. All this reminds me of the tenuous similarity between rheological models and the products of nature.

B.S.R. BULLETIN

Report of the Editor, 1970

Perhaps the most obvious feature about the Bulletin of the immediate past is that each edition now carries the year, issue number and also the volume number. It is hoped that this will be a useful feature to members who wish to collect the issues.

Inside the covers there has been a modest increase in the technical content, but now that there is a Working Party on Publications the future shape of the Bulletin is uncertain, it is not anticipated that the original aim of a considerable scale-up of technical content can be pursued until a decision is reached by the Council on the matter of sponsoring a separate technical journal.

An attempt has been made to cover a variety of interests and to communicate useful information. Several enquiries have been received about the computer programs in the abstracts and have been passed to the authors. In addition to the usual four editions of the Bulletin in the past year, the Gold Medal paper was also published as a supplement to No. 4 Volume 12 (1969). It has been a year in which some small developments have been made in the layout of the Bulletin to improve readability.

The editor would like to acknowledge those who have contributed to the Bulletin not only over the past year, but also in previous years, and to encourage future efforts in this direction.

J. HARRIS.

ANNUAL REPORT 1969-70

Rheology Abstracts

It is now almost twelve months since I succeeded Mr. Warburton, and during this period four issues of Abstracts have appeared, much as before. These issues comprise 762 abstracts of papers from learned journals, 55 abstracts of papers presented at the Society's conferences, and four book reviews, as well as the annual author and subject indexes (the latter painstakingly compiled by Dr. Mardles) and the

explanation of the System of classification of papers on non-Newtonian Flow.

A list of the 26 members who have been Abstractors during the year is included as an appendix to this report. The names of the 110 or so journals which they cover at present are given in lists which appear in the March and September 1970 issues. The Society is much indebted to these gentlemen for their continued support, which is most time-consuming (two abstractors cover 16 journals each). There are, however, still a number of journals which we miss, and I would be very glad to hear from any member who would be prepared to help in this way.

On January 9th of this year a meeting in London was attended by 12 abstractors and a representative from Pergamon Press. Various matters concerning the running of Abstracts were discussed, after which we had an enjoyable lunch. Relations with our publisher remain excellent; so far their internal reorganisation has had no effect on our journal.

Since 1968 the System of classification of papers on non-Newtonian Flow has been employed in many abstracts. In order to assess how much use is being made of the classification, which involves extra work for abstractors as well as extra production costs, I have included in the September issue a questionnaire postcard. I hope that as many of these as possible will be returned, preferably with comments. The results will be of considerable interest, not least to the Working Party who devised the System.

Appendix

List of Abstractors, 1969-70

Dr. H. A. Barnes (Aberystwyth)
Dr. K. M. Beazley (St. Austell)
Dr. M. F. Culpin (Pontypool)
Dr. E. J. Dickinson (Australia)
Mr. C. B. Duckham (Salford)
Mr. F. A. Glover (Shinfield)
Dr. M. J. Groves (Chelsea)
Dr. D. W. Hadley (Reading)
Mr. R. W. Higman (Warren Spring)
Dr. P. Howard (Guildford)
Mr. J. F. Hutton (Chester)
Mr. H. A. Johns (Reading)
Dr. F. M. Leslie (Strathclyde)
Dr. D. R. Oliver (Birmingham)
Dr. J. R. A. Pearson (Cambridge)

Dr. C. J. S. Petrie (Newcastle)
Dr. M. C. Phillips (Chester)
Mr. R. N. F. Pinfold (Melton Mowbray)
Dr. A. Plochocki (Poland)
Dr. J. E. Romain (Belgium)
Dr. R. Roscoe (Newcastle)
Mr. J. M. Smith (Swansea)
Mr. G. R. Sothern (Brunel)
Dr. K. Walters (Aberystwyth)
Mr. R. W. Whorlow (Guildford)
Professor V. Wright (Leeds)

A. EVANS.

REPORT OF HON. TREASURER, 1969-70

The audited accounts of the Society show an excess of expenditure over income for the year of £34 17s. 6d. compared with an excess of income over expenditure last year of about £115. This small deficit is due to a combination of factors which will not generally occur together and the finances of the Society are likely to remain approximately in balance for the next year.

Two large items of expenditure this year arose from the preparation of a Membership List (about £200) and the purchase of a new addressograph machine (£47 10s. 0d.). Both these items are included under Membership Secretary's expenses. Of the £166 under Production Costs for Abstracts, nearly half was incurred in the previous accounting year but paid during 1969-70. On the other hand the cost of the Bulletin was less than in the previous year and a net profit was made on Conferences.

The Leatherhead Bond matured during the year and we were able to reinvest the money at a more favourable rate with Brentwood.

As usual the major item of income is our share of the profits from Rheology Abstracts and a great debt is owed to the Editor and to Abstractors, not only for providing a useful service to Members but also for providing a source of income for the Society. I hope that more members will offer help so that the load can be spread more evenly.

R. W. WHORLOW.

BRITISH SOCIETY OF RHEOLOGY

Balance Sheet as at 30th June, 1970

ASSETS

Brentwood U.D.C. 9½% Bond	...	...	1,500	0	0
Debtors	...	...	906	14	3
Cash at Lloyds Bank Ltd.	...	...			
Deposit Account	...	...	562	17	6
Current Account	...	...	45	16	2
				608	13 8
				3,015	7 11

Less

CURRENT LIABILITIES

Sundry Creditors	...	...	...	...	66 17 6
------------------	-----	-----	-----	-----	---------

NET ASSETS	...	...	...	...	
					£2,948 10 5

Represented by:—

GENERAL FUND

As at 1st July, 1969	...	...	...	2,983	7 11
Deduct Excess of Expenditure over Income	...	...	...		
for the year	...	...	...	34	17 6
				£2,948	10 5

R. W. WHORLOW, Hon. Treasurer.

We have examined the above Balance Sheet and annexed Revenue Account together with the books and vouchers of the Society, and certify them to be in accordance therewith. We have not inspected the membership records.

ALFRED SIMMONS & CO.,

Chartered Accountants.

The Market Hall,
Redhill, Surrey.
20th August, 1970.

Revenue Account for the year ended 30th June, 1970

EXPENDITURE

14	Clerical Services	...	...	...	9	3	3
86	Printing and Stationery	...	...	...	16	1	1
10	Postage	...	...	...	21	5	8
	Travelling and Committee Expenses						
147	Officers and Council	...	...	...	161	11	1
150	Research Committee	...	...	...	35	0	0
75	B.S.I. Committee	...	...	...	164	6	4
—	Publications Working Party	...	...	...	36	15	5
571	Bulletin—Production Costs	...	...	...	397	12	10
—	Abstracts—Production Costs	...	...	...	458	4	10
192	Membership Secretary—Expenses	...	...	...	166	5	5
36	Professional Fees	...	...	...	503	17	6
34	Gold Medal Competition Expenses	...	...	...	30	5	0
9	General Expenses	...	...	...	119	9	0
					20	15	0
					1,742	19	7

INCOME

541	Annual Subscriptions and Entrance Fees				511	3	2
	Rheology Abstracts and Bulletin						
893	Publisher (Abstracts) ...	884	9	0			
3	Bulletin Subscriptions ...	3	0	0			
					887	9	0
	Investment Income—gross						
59	Bank Deposit Interest ...	62	7	3			
97	Leatherhead 6½% Bond ...	38	6	8			
—	Brentwood 9½% Bond ...	73	7	11			
					174	1	10
	Conferences—net income						
	Bradford 1968 ...	6	0	0			
-155	Strathclyde 1969 ...	84	11	9			
	Pharmacy 1970 ...	44	16	4			
					135	8	1
							1,708 2 1
-115	EXCESS OF EXPENDITURE OVER INCOME FOR THE YEAR ...						£34 17 6

MEMBERSHIP SECRETARY'S REPORT, 1969-70

About 50 new members have joined the Society since September 1960. The membership now stands at approximately 690.

One member has resigned and I have also heard recently of a member who died whilst climbing in the Cairngorms.

The Membership Secretary would be most grateful to all those members whose membership subscription is paid by their employer, if the member's name is clearly indicated by the accountant when the cheque is issued. "Anonymous" donations to the Society, in this respect, can be an embarrassment.

B. Warburton.

RESEARCH COMMITTEE CHAIRMAN'S REPORT, 1969-70

There have been no meetings of the Research Committee this year. Those matters arising that have been dealt with by the Committee in earlier years have been for the most part dealt with directly by the Council or its officers.

In particular, the Joint Working Party on non-Newtonian flow (of the Institution of Chemical Engineers and the British Society of Rheology) has produced a final report. This will be published later this year by the Institution of Chemical Engineers and it is hoped to make copies available to British Society of Rheology members. Its main recommendation is that an institute be established, with government help, to study non-Newtonian flow, along the lines of the Institutes of Tribology recently established as a result of the Jost Report. Your Council noted the strongly engineering and industrial bias of the proposal and consider that a more specifically rheological and fundamental Research Institute might be of more interest to the majority of British Society of Rheology members, and just as likely to succeed. It hopes that the Society will be represented in any developments arising following publication of the Report.

J. R. A. Pearson.

REPORT OF WORKING PARTY ON PUBLICATIONS

The Bulletin has recently included a number of technical papers and the Council has set up a Working Party to consider whether this practice should be continued, discontinued or extended. The present cost of publishing the Bulletin is close to £1 per member and any extension of its scope would be expensive.

The Working Party has been considering whether there is a strong case for a new British Journal to publish rheological papers and has

presented a report to Council but no decisions have yet been made pending further enquiries. The following notes are based on the above report and give some results of a questionnaire sent to members and to non-members in the N.E.L. Survey of Rheological Research in Britain, 1968. The Working Party and Council would like to thank all those who replied to the questionnaire and particularly those who made comments on the proposals on the reply cards or in separate letters.

1. Constitution of Working Party

A. Evans
D. W. Hadley
J. Harris
A. Please
R. W. Whorlow (Convenor)

2. Extract from Questionnaire

We have in mind a major international scientific journal published quarterly or bi-monthly. Papers would be published only if the Editorial Board, advised by referees, considered them to be of a high standard. Papers read at Conferences of the Society would be published subject to refereeing and approval by the Editorial Board.

Rapidity of publication is considered essential and every attempt would be made to ensure publication within a maximum of nine months. Short "notes" or "letters" would be published more rapidly.

Please enter the answers to the following questions on the enclosed postcard. Assuming that a journal of the kind proposed had been in existence for the last THREE years: —

- (1) How many papers would you probably have submitted to it?
- (2) Of these papers how many have been published, or accepted for publication, elsewhere?
- (3) How many papers of a predominantly rheological character have you published in the last three years?
- (4) Would you prefer
 - A. A purely technical journal with the B.S.R. Bulletin continuing in a shorter form.
 - or B. A journal carrying technical papers and B.S.R. news, bearing in mind that a substantial increase in subscription would be necessary in this case.

Question 4 was deleted from the Questionnaire sent to non-members.

3. Replies to Questionnaire

In most cases replies are quoted in the form: (Members' replies) + (Non-members' replies)

Questionnaires distributed (approx.) ... 630 + 600
 Cards or letters received by 3.8.70 ... 107 + 132
 (including a few cards returned on behalf of two authors)

Q. 4 (Members only): A 79 B 14
 No preference or neither 14

Q. 1 128 + 52 from 48 + 29 authors

Q. 2 104 + 47

Q. 3 238 + 134 (including 104 + 47 from Q. 2)

Comments. (Subjective analysis by R. W. W.)

			<i>Non-authors</i>	<i>Authors</i>	<i>Total</i>
Firmly anti	...	...	5 + 6	8 + 9	28
Mildly anti	...	...	3 + 2	2 + 6	13
Neutral or conditional	...	...	2 + 1	7 + 0	10
Mildly pro	...	...	2 + 1	4 + 0	7
Strongly pro	...	...	1 + 2	8 + 2	13

Review of Comments

Adverse comments were mainly connected with the undesirability of proliferation of journals coupled with statements that authors found no difficulty in publishing good papers. Several respondents plead with us not to publish yet another journal. Support came almost entirely from members.

R. W. WHORLOW.

REPORT ON THE ANNUAL B.S.R. AUTUMN CONFERENCE

"Rheology in Industry," Shrivenham, 7th-10th September, 1970

The Autumn Conference of the Society attracted over 100 registrants to the Royal Military College of Science, and included rheologists from U.S.A., Canada, France, Germany, Belgium, Holland, Switzerland and Italy. The title of the Conference, "Rheology in Industry," was chosen to show how diverse are the ways of rheology in industry; in this aim, it certainly succeeded.

Tuesday morning saw the opening of the Conference with an address by Dr. L. Grunberg, the retiring President of the Society. This discourse, philosophical yet practical, stressed the need for application of fundamental rheological knowledge to industrial problems, and left us with some searching questions to chew over. Having given the meeting a good send off, Dr. Grunberg then took the chair for the remainder of the morning session. The first paper, by Dr. J. C. Weeks (I.C.I., Welwyn) applied Fourier analysis to the flow of polymer melts and showed how correlation exists between steady shear flow and dynamic viscoelastic behaviour. This relation was then used to predict the

behaviour of melts under the commercially important conditions of applications of high stress applied for short times. L. W. Turner, R. Shah and D. Mugridge (Yarsley Research Laboratories) continued the programme when Mr. Turner described techniques for measuring the viscosity of material flowing in the screw of an injection moulding machine, and showed how such knowledge could be used in the control of that machine. The morning session concluded with a paper by R. F. Pinfold (Bostik, Leicester) who demonstrated how an "old-fashioned" type of conventional plastometer could be used to study curing and similar temperature-time effects in elastomers and liquid polymers.

Lunch, and the usual bewildering Shrivenham cold table or substantial hot dishes, and then back to work. The President-elect, Prof. J. Lamb, took the chair and introduced the first speaker. This was Dr. D. C.-H. Cheng, of Warren Spring Laboratory, who detailed the general lines of sponsored research carried out by that organisation in the field of applied rheology. This paper should have been followed by one by Dr. J. David, of Prague, but Dr. David was unfortunately unable to attend the meeting, and the next speaker was Prof. M. Williams (University of Utah and Imperial College, London). He spoke on the mechanics of adhesive bonding between two continua. This paper, a balanced blend of theory and experiment, concluded with a description of experiments being carried out to find out why marine barnacles cling to surfaces as tenaciously as they do, and to try to isolate some of the magic adhesive that helps them do it. In the absence of Dr. K. Walters (University College of Wales, Aberystwyth), Dr. H. Barnes read the next paper. This described how properties associated with non-Newtonian behaviour, and viscoelastic behaviour in particular, could be used advantageously in such applications as improving flow rates in pipes.

A quick cuppa, and so to the closing papers of the day. First, R. Zangger (Contraves, Zurich) related to a clearly sympathetic and understanding audience the pitfalls and errors that could arise in the practice of rotational viscometry. P. Langborne (N.E.L.) closed the day's proceedings by showing how the characteristic Oldroyd constants of a fluid could be obtained from straightforward measurements made with a Weissenberg rheogoniometer.

The day's business, however, was not quite done, since the Society's A.G.M. had yet to convene, which it did after dinner. Well attended and lively, the main outcome of this meeting was reflected in the changes which it approved in the composition of Council. Dr. Grunberg handed over the metaphorical Presidential chain of office to Prof. J. Lamb, while Dr. Barbara Neumann transferred the secretarial pen and aspirins to Dr. K. M. Beazley. New Ordinary Members of Council were Mr. J. F. Hutton and Dr. J. M. Hobbs in place of two stalwarts, Mr. R. Cole and Mr. A. T. J. Hayward. Votes of thanks to the retiring

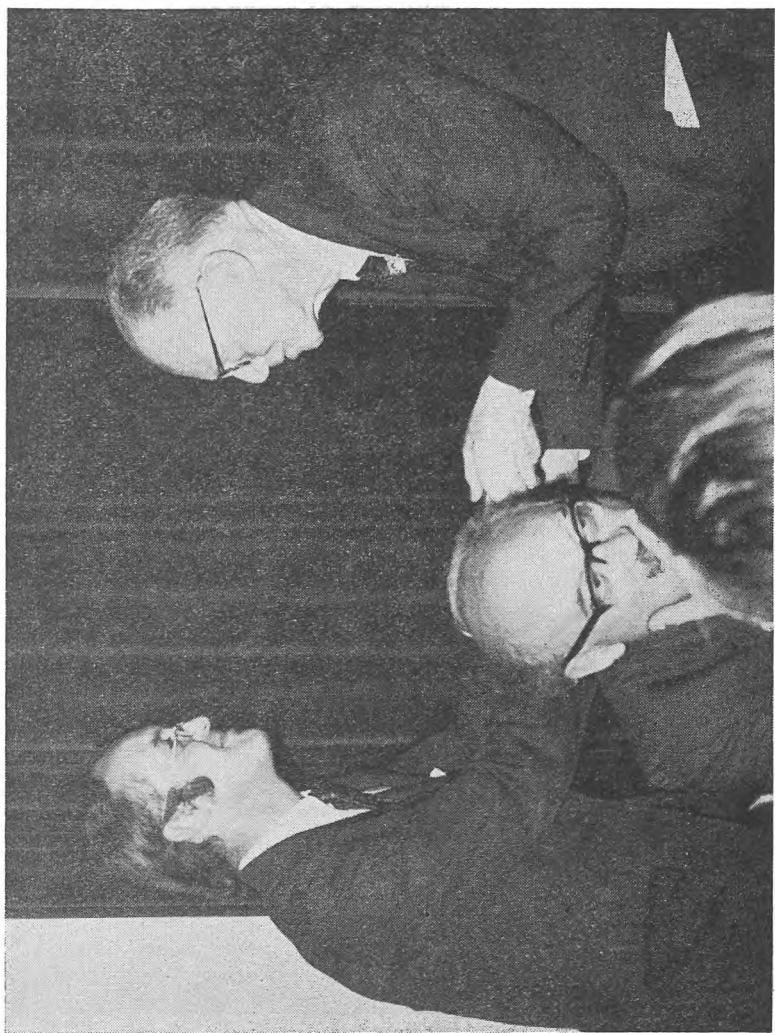
President and Secretary, the Council and the abstractors were proposed, seconded and carried with acclamation.

Wednesday morning saw four papers, each dealing with a rather different material. Dr. Scott-Blair was chairman and the first paper which he introduced was by D. K. H. Briggs (Coal Tar Research Association, Cleckheaton) who related viscoelasticity measurements made with a pendulum impact tester on tar and bitumen road aggregate binders, to their ability to absorb road traffic stresses over a wide temperature range. Tars gave way to polyurethane foam, whose rheological properties both during production and in the finished product were described by M. M. Cross (I.C.I., Blackley). G. H. Goulbourn (British Paints, Newcastle) described the use of a Rossi-Peakes flow tester as a control instrument for injection moulding. Data provided by this instrument enabled the viscosity of thermosets used for injection moulding to be measured and hence the flow processes occurring during moulding to be determined. C. A. Street (Rowntrees, York) wound up the session with a paper by himself and Miss C. A. Burnett, which reported the results of rheological properties of confectionery systems as measured with a Weissenberg rheogoniometer. Besides its technical content, this paper was also appreciated for the distribution of samples of one of the systems concerned, which were tested on the spot by oral degustation processes.

By the afternoon, the weather (which had not been exactly gentle) had moderated sufficiently to enable those members who chose to go on a scenic tour of the Downs and Thames Valley to have at least a sporting chance of seeing that scenery. Those preferring something a little more like a busman's holiday could choose between trips to a meat products factory, a paper mill, a cigarette factory, and a car body repair works.

The Conference dinner held that evening proved to be the success anticipated. Highlight of it was the presentation of gold medals to the two surviving members of the trio who had founded the British Rheologists' Club, forerunner of the Society, 30 years ago. Recipients of the award were Dr. G. W. Scott-Blair and Dr. V. G. W. Harrison. (The third founder member was Dr. H. R. Lang, who had passed away some years earlier.) The presentation was made by the President, Prof. J. Lamb, and both gold medallists "suitably responded," to use the time honoured cliché.

Thursday's morning session was chaired by Dr. C. Chaffey, of Toronto, and the ball set rolling by F. N. Cogswell (I.C.I., Welwyn) who developed the equations of flow of non-Newtonian materials, such as polymer melts, when extruded through converging dies. Predicted behaviour was compared with observed results, with satisfactory agreement. Printing inks were the next material to be dealt with, and a technique for dynamic measurement of their viscoelastic properties was given by Dr. A. J. B. Spaul (Brunel University) in describing work



Dr. G. W. Scott-Blair receives his Founders Gold Medal from the President



Dr. V. G. W. Harrison receives his Founders Gold Medal from the President

done by himself and G. A. Lewis. Dr. K. M. Beazley (English China Clays, St. Austell) described how he and Mrs. M. Climpson had used optical techniques to measure millisecond interval penetration of water into paper, such as occurs in the practice of paper coating. Defect zones in the paper structure are supposed to control the initial rush of water into the sheet. The morning session closed with a paper by R. Smith (Goodlass Wall, Liverpool) who reported how measurements made on a Rotovisko viscometer at low rates of shear could be used to characterise the ability of paints to flow out after application.

The last lunch-hour came and went, and 2.15 p.m. saw Prof. J. Smith take the chair for the last two papers of the meeting. Work done at T.N.O., Delft, by J. L. S. Wales and J. van Leeuwen was described by the former author. They had worked with amorphous thermoplastics and had attempted to predict the level of birefringence in injection moulded objects from measurements made during isothermal flow of polymer melts in slit viscometers, and to relate this birefringence to the degree of orientation imparted to such moulded objects. The closing paper by Dr. C. Chaffey (University of Toronto) described measurements which he and P. Leroux had made, using a Ferranti-Shirley viscometer, to show what effects certain surfactant materials had on the viscosity of motor oils, and to relate those results to the structure of the surfactant.

A few well chosen words of thanks from the chairman and the Conference was over. As stated before, the Conference certainly brought out the diverse nature of rheology as practised in industry. A well-received, useful and instructive conference, too, if the level of discussion following the papers is any yardstick, since on a number of occasions discussion had to be curtailed to keep the programme to time—and that, surely, is better than 20 papers received in bored silence! As usual, the powers-that-be at R.M.C.S. looked after our creature comforts excellently, and we are grateful for the part which they played in this conference.

K. M. BEAZLEY.

REPORT ON THE VICTORIAN BRANCH

On Thursday, 23rd April, 1970, at 7.30 p.m., a joint meeting of the Branch and the Polymer Group of the R.A.C.I. was held at Clunies Ross House.

DR. L. M. GILLIN, B.Met.E., M.Eng.Sc., Ph.D.

"COMPOSITE MATERIALS"

Dr. Gillin, who has initiated both basic and applied research programmes on fibre reinforced composites at Aeronautical Research Laboratories, Fishermen's Bend, described them with particular atten-

tion to high strength fibre-reinforced composites. Why are they strong? Why do they have a high specific stiffness? How much will they cost? Can normal fabrication methods be used? What of fatigue and creep? These and other points were considered. Special emphasis was given to Polymeric matrices and an evaluation of the engineering potential and application of these composite materials. A buffet meal was served in the Sciences Club at 6.45 p.m.

OTHER NOTICES

Advanced Courses

Monash University, Department of Chemical Engineering

A series of short lecture courses was given to post-graduate research students in the department during 1970. Topics:

- Mathematical Methods
- Reactor Design
- Stability of Reactive and Non-Reactive Systems
- Rheology and Flow of Non-Newtonian Systems
- Biochemical Engineering

All the topics listed were of 12 hours' duration except Mathematical Methods which took approximately 30 hours.

1st Pacific Chemical Engineering Congress, 11th-14th October, 1972

Members of the Branch are invited to participate in this International Conference to be held in Japan in 1972. Details available to date are:

A.I.Ch.E. and S.C.E.J. will sponsor the 1st Pacific Chemical Engineering Congress at the Kyoto International Conference Hall, Kyoto, Japan. Meeting Chairmen: Dr. D. A. Dahlstrom, The Eimco Corp., 301 South Hicks Road, Palatin Ill., and Dr. H. S. Kemp, Eng. Services Div., E.I. DuPont de Nemours and Co. Inc. Wilmington, Delaware. For further information contact either Joel Henry, A.I.Ch.E., 345 E. 47th Street, New York, N.Y. 10017, or Dr. T. Yatagaya, President, The Society of Chemical Engineers, Japan, Kyoritsu Building, 6-19 4-chrome, Kohinata, Bunkyo-ku, Tokyo. Preprint deadline 1st May, 1972.

Proposed Sessions

Engineering Fundamentals

- Thermodynamics and Molecular Engineering
- Transport Phenomena and Rheology
- Transport Operations
- Particle Mechanics and Powder Technology
- Chemical Kinetics and Reaction Engineering

Engineering Fundamentals and Industrial Problems

Mixing and Dispersion
Particle Mechanics and Powder Technology
Chemical Kinetics and Reaction Engineering
Chemical Engineering under Extreme Conditions
Biochemical and Biomedial Engineering

Industrial Problems

Separation Techniques
Materials of Construction
Process Design and Control Engineering
Air and Water Treatment
New Processes and Products
International Management Marketing and Cost Engineering
Loss Prevention and Safety

D. V. BOGER, Secretary B.S.R.,
Department of Chemical Engineering,
Monash University,
Clayton, Vic. 3168 (Tel. 541-3427).

DR. GEORGE WILLIAM SCOTT-BLAIR, M.A., Ph.D., D.Sc.

Drs. Scott-Blair and Harrison were recipients of B.S.R. Founders Gold Medals at the Annual Autumn Conference of the B.S.R. We publish here a summary of Dr. Scott-Blair's career and hope to publish a similar article on Dr. V. G. W. Harrison in the next edition of the Bulletin.

Fellow of the Royal Institute of Chemistry; Fellow of the Institute of Physics.

Hons. degree in Chemistry, University of Oxford. First research under Sir Cyril Hinshelwood. Specialised in colloids.

During two years' experience as Colloid Chemist in an industrial laboratory, worked on viscosity of flour suspensions.

For ten years, a member of the Physics Department, Rothamsted Experimental Station (Goldsmith Fellow). Worked exclusively on rheology—soils, clays, flour doughs, honey, etc.

Rockefeller Fellowship for one year at Cornell University. Worked under Prof. W. D. Bancroft on rheology of ceramic clays. With Dr. R. K. Schofield, published first quantitative study of radius anomalies in pastes flowing through tubes (1930). (In 1931, Fahraeus and Linquist first studied this phenomenon in blood.)

Foundation member [American] Society of Rheology. Presided at a Session of the first Conference, Washington D.C. 1929.

From 1937, Head of first, Chemistry and later, Physics Department, National Institute for Research in Dairying, University of Reading, England. Retired 1967. Worked on rheology of dairy products; also on properties of bovine and human cervical mucus. Invented tests for oestrus and for pregnancy in cows. Co-operated with gynaecologists on relationships between rheology of cervical mucus and hormonal abnormalities in women. Worked on rheology of pre-natal mammary secretions in women and on rheology of human synovial fluids. Published papers in all these fields. Concerned with rheological properties of semen. Worked on Flow and Coagulation of Blood under grant from (U.S.) National Institutes of Health 1962-67.

Foundation member, first Secretary and later President of British Rheologists' Club, later British Society of Rheology. During second World War, part time seconded to work on rheology of plastics with Electrical Research Association. Member of Deutsche rheologische Gesellschaft and presented with their Freundlich Memorial Medal. Honorary Member of the Groupe français de Rhéologie.

Represented International Union of Physics on International Commission on Rheology (I.C.S.U.). Lectured on Colloids and on Rheology at Sir John Cass Institute and at London (Regent) Polytechnic.

Three times accepted invitations to lecture and consult on (mainly) veterinary and medical rheology in Israel. Lectured to various Societies in France, including Groupe français de Rhéologie. Lectured on rheology in Holland (Agricultural University of Wageningen) and also in W. Germany, Portugal, Hungary, Sweden, U.S.A.

Organising Secretary, 2nd International Congress on Rheology, Oxford, England, 1953.

Author of two text books on general rheology (one translated into German). Author of book on general principles of measurement. Edited and partly wrote book on rheology of foodstuffs (translated into Japanese). Joint author of book on agricultural rheology (with Prof. M. Reiner) (translated into Japanese). Author of "Elementary Rheology" (Japanese and French trans.).

Published two lectures given at London University on Rheology in Pharmacy and Medicine and gave courses of lectures at London School of Pharmacy on rheology.

Published some 250 scientific papers and lectures on rheology during the past 45 years.

Wrote articles on rheology for Chambers' Encyclopaedia and Encyclopaedia Britannica and the Encyclopaedic Dictionary of Physics.

Co-Editor in Chief of series of Rheology Monographs published by N. Holland Publishing Co., Amsterdam, Holland.

Co-Editor in Chief of journal "Biorheology."

Gold Medal (Poiseuille Medal) of Internat. Soc. of Haemorheology (now "Biorheology") 1969.

Now working part-time on blood coagulation at Oxford Haemophilia Centre, and consulting work on rheology, especially of food-stuffs.

Special Notice to Members—Membership Secretary

At its meeting on 28th September Council accepted with regret the resignation due to illness of Mr. Warburton from the office of Hon. Membership Secretary. The President was asked to express to Mr. Warburton the hope of members that he would soon be restored to full health and to thank him for his work as an Officer and as a Member of Council of the Society.

Mr. R. R. Addis very kindly agreed at short notice to accept appointment by Council as Hon. Membership Secretary until the next Annual General Meeting. All membership dues and other correspondence concerning membership should therefore be addressed to:—

Mr. R. R. Addis,
7 Dale Gardens,
Little Sandhurst,
Near Camberley, Surrey.

CAHIERS DU GROUPE FRANCAIS DE RHEOLOGIE

The Society receives a complimentary copy of "Cahiers du Groupe Français de Rhéologie." This publication appears approximately twice yearly and contains the full illustrated text of papers presented at G.F.R. conferences.

The contents are noted in "Rheology Abstracts," but few British libraries subscribe to the journal. Members may therefore welcome the opportunity of borrowing the Society's copy.

The latest issue (Vol. 2, No. 3; 80 pages) contains the papers presented at the October 1968 meeting devoted to "Rheology in Relation to Structure." This and earlier issues may be borrowed from Dr. D. W. Hadley, J. J. Thomson Physical Laboratory, Whiteknights, Reading RG6 2AF.

B.S.R. AUTUMN CONFERENCE 1971

The Autumn Conference of the British Society of Rheology for 1971 will be held during September. This conference will be of a general nature and will not bear a specific title; it is, however, proposed to devote sessions specifically to polymers, disperse systems and to instrumentation. Papers on these, and other rheological subjects, are invited, and prospective authors are asked to notify their intention to submit a paper to:—

Mr. A. Please,
Materials Section,
Road Research Laboratory,
Crowthorne, Berks.,
RG11 6AU.

Such notification should be made as soon as possible. Titles and abstracts of papers will be required by 1st May, 1971.

Since the scope of this conference will be quite wide, it may be necessary to compose the programme by selecting papers from those offered, should the number of papers offered prove exceptionally large.

SOCIETY OF RHEOLOGY (U.S.A.)

1970 Bingham Medallist

Dr. Anton Peterlin

Dr. Anton Peterlin, Director of the Camille Dreyfus Laboratory Triangle Research Institute, Durham, North Carolina, has been selected as the recipient of the 1970 Bingham award.

The award will be made at the annual meeting.

N. Tschoegl is chairman of the Bingham Award Committee.

Smoker Monday evening at Art Institute honouring Dr. Peterlin.

1971 Winter Meeting

University of Utah, Salt Lake City, Utah

1st-3rd February, 1971

Prof. E. B. Christiansen, arrangements chairman, at the Department of Chemical Engineering, University of Utah, Salt Lake City, Utah, 84112, announces that the 1971 Winter Meeting of the Society will be held in Merrill Engineering Building on campus 1st-3rd February, 1971. These dates occur after the Gordon Conference on Polymers.

THE INSTITUTION OF CHEMICAL ENGINEERS

North-Western Branch

Symposium on Non-Newtonian Technology

4th May, 1971, University of Salford

Provisional titles and order of papers.

Chairman, not yet announced.

1. "Non-Newtonian Flow around a Rotating Sphere." J. V. Kelkar, R. A. Mashelkar, J. Ulbrecht (University of Salford).
2. "Non-Newtonian Flow around a Rotating Disc." J. Ulbrecht, R. A. Mashelkar (University of Salford).
3. "Alternative Stable Modes of Flow in Gate or Anchor Agitated Systems." J. M. Smith (University College of Swansea).

4. "Dynamics of a Non-Newtonian Flow in a Vessel stirred by a Helical Agitator." V. S. Chavan, A. S. Jhaveri, J. Ulbrecht (University of Salford).
5. "Scale-up in the Mixing of very Viscous Non-Newtonian Fluids and Pastes." D. C.-H. Cheng (Warren Spring Laboratory).
6. No title yet.

Further details from: —

C. B. Duckham,
Department of Chemical Engineering,
University of Salford,
Salford M5 4WT, Lancs.

THE POLYTECHNIC OF THE SOUTH BANK

DEPARTMENT OF CHEMISTRY AND CHEMICAL TECHNOLOGY

PLASTICS RHEOLOGY

A course of about 20 lectures will be given on Tuesday evenings from 5th January, 1971, commencing 5.30 p.m.

Plastics Rheology

Commencing at 5.30 p.m. on Tuesday, 5th January, 1971. Lecturer: R. S. Lenk, B.Sc., F.R.I.C., A.P.I.

This course which will be held on Tuesday evenings and will be of about 20 weeks duration is intended for engineers, physicists, chemists and technologists in industry and in higher education. No specific entry conditions are laid down, but students will be expected to be familiar with simple calculus and have H.N.C., H.N.D., a university degree or its equivalent.

Although the course will start from first principles, it will go on to deal in depth with the deformation and flow of plastics and will pay particular attention to the application of theory to processing and product design.

Syllabus:

The philosophy of rheology—states of matter.

Mathematical notation.

The equations of continuity, momentum and energy.

Rheological equations. The power law.

Analysis of flow problems in extrusion, calendering and injection moulding.

Flow defects and their causes. Melt fracture, melt tensile strength and melt elasticity.

The mechanism of viscous flow. Effects of temperature, pressure, shear rate and molecular weight on viscous flow.

The activation energy of viscous flow.

Rheology and die design.

"Solid state"—small deformations.

"Solid state"—large deformations.

"Solid state"—oscillatory deformations.

The strength of plastics and types of failure in relation to product design.

Rheology and morphology.

Rheological instruments.

Laboratory demonstrations.

CHEMECA '70

Abstract of Programme

The titles of papers and names of authors, with affiliation, are given below for each symposium. These are arranged as far as possible in the order of presentation. Where there are two or more authors to a paper, the asterisk indicates the one expected to present the paper.

PARTICLE MECHANICS

Symposium Chairman: D. F. Kelsall.

"The Effect of Free-Stream Turbulence on the Drag Coefficient of Spheres" by P. H. T. Uhlherr* and C. G. Sinclair (Dept. of Chemical Engineering, Monash University, Melbourne).

"The Motion of Particles in Turbulent Gas Streams" by R. Clift and W. H. Gauvin* (Dept. of Chemical Engineering, McGill University, Montreal).

"Multi-Orifice Distributors in Fluidised Beds" by S. Fakhimi and D. Harrison* (Dept. of Chemical Engineering, University of Cambridge, U.K.).

"Initial Motion of a Bubble in a Fluidised Bed" by T. C. Sandford and L. S. Leung* (Dept. of Chemical Engineering, University of Queensland, Brisbane).

"Back Mixing of Gas in Fluidised Beds" by C. J. Hamilton, C. Fryer and O. E. Potter* (Dept. of Chemical Engineering, Monash University, Melbourne).

"Particle Elutriation from Gas-Fluidised Beds" by W. J. Ryan (Australian Mineral Development Laboratories, Frewville, South Australia).

"Continuously Slugging Fluidised Beds" by P. W. K. Kehoe and J. F. Davidson* (Dept. of Chemical Engineering, University of Cambridge, U.K.).

"A Study of Pulsed Fluidisation of Fine Powders" by P. G. Alfredson* (A.A.E.C. Research Establishment, Lucas Heights, N.S.W.) and I. D. Doig (Dept. of Chemical Engineering, University of N.S.W., Sydney).

"The Development of a Mathematical Model for Large-Scale Mills" by B. K. Loveday* and A. T. Tolmay (National Institute for Metallurgy, Cottesloe, S. Africa).

BIOCHEMICAL AND BIOMEDICAL ENGINEERING

Symposium Chairman: L. Dintenfass.

- "Couette Oxygenation and Blood Damage" by M. Overcash (Dept. of Chemical Engineering, University of Wisconsin, Madison, Wis., U.S.A.).
- "Analysis of Blood Flow in Renal Medulla" by J. Norman and S. N. Vigh* (Dept. of Chemical Engineering, University of N.S.W.).
- "Rheology of Blood: Viscosity Factors in Blood Flow, Ischaemia and Thrombosis" by L. Dintenfass (Dept. of Medicine, University of Sydney).
- "Microspheres: A New Concept in Artificial Kidneys" by T. M. S. Chang (Dept. of Physiology, McGill University, Montreal, Canada).
- "Piezoelectric Phenomena in Blood, Blood Vessels (and Blood Coagulation)" by E. Fukada (Inst. of Physical and Chemical Research, Tokyo, Japan).
- "Structure and Function of Cartilage" by P. F. Millington (Bioengineering Unit, University of Strathclyde, Glasgow, U.K.).
- "Dispersion of Oil in Water in Gas Bubble Columns and Agitated Vessels" by F. Yoshida and T. Yumada (Chemical Engineering Dept., Kyoto University, Kyoto, Japan).
- "Computer Experiments on the Cornea: Epithelial Pump Rate and Electrical Properties" by M. H. Friedman (Applied Physics Laboratory, The Johns Hopkins University, Maryland, U.S.A.).

RHEOLOGY AND MIXING

Symposium Chairman: D. V. Boger.

- "Flow Behaviour of Colloidal Suspensions" by R. J. Hunter* and J. P. Friend (Dept. of Physical Chemistry, University of Sydney).
- "The Rheology of Suspensions of Discs" by P. S. Lingard and R. L. Whitmore* (Dept. of Mining Engineering, University of Queensland).
- "Studies on the Rheology of Rapidly Setting Non-Newtonian Suspensions" by B. R. Gupta*, N. K. Purohit and A. N. Roy (Dept. of Chemical Engineering, Indian Institute of Technology, Kharagpur, India).
- "Predicting Non-Newtonian Entrainment in Steady Withdrawal" by J. A. Tallmadge (Dept. of Chemical Engineering, Drexel University, Philadelphia, Pa., U.S.A.).
- "Dissolution of Freely Suspended Solid Particles in an Agitated Non-Newtonian Fluid; Rheology and Mass Transfer" by T. K. Tuoc and R. B. Keey* (Dept. of Chemical Engineering, University of Canterbury, Christchurch, New Zealand).
- "Extrusion of Brown Coal" by G. R. Rees and D. G. Evans* (Dept. of Chemical Engineering, University of Melbourne).
- "Drop Break-Up in a Stirred Liquid-Liquid Contactor" by D. E. Brown* and K. Pitt (Dept. of Chemical Engineering, University of Manchester Institute of Science and Technology, U.K.).
- "The Spectrum of Fluid Shear in a Mixing Vessel" by J. M. Oldshue (Mixing Equipment Co. Inc., Rochester, N.Y., U.S.A.).
- "The Effect of Fluid Properties and Impeller Design on the Performance of Helical Ribbon Mixers" by K. R. Hall* and J. C. Godfrey (Division of Chemical Engineering, C.S.I.R.O., Melbourne).
- "Segregation Intensity Distribution in a Tank Mixer with and without Second Order Reaction" by G. K. Patterson (Dept. of Chemical Engineering, University of Missouri-Rolla, Missouri, U.S.A.).

SCIENTIFIC MANAGEMENT IN THE PROCESS INDUSTRIES

Symposium Chairman: R. H. Buchanan.

Sessions at Melbourne and Sydney.

(a) Melbourne Sessions, Wednesday, 19th August, 9.15 a.m.-4.45 p.m.

(i) **Conception and Development of Projects** (9.15 a.m.-12.30 p.m.).

"Management Planning" by C. W. Davis (Colonial Sugar Refining Co. Ltd., Sydney).

"Developing New Technology—A Challenge to Australian Management" by R. Ward (B.H.P. Co. Ltd., Melbourne).

"Development of Management and Marketing Strategies in the Chemical Industry" by B. W. Scott (W. D. Scott & Co. Pty. Ltd., North Sydney).

"New Venture Analysis and Selection in Australia" by H. House (C.S.R. Chemicals Pty. Ltd., Rhodes, N.S.W.).

"The Significance of Size" by D. B. Lloyd (London, U.K.).

(ii) **Environmental Forces Affecting Industry** (1.30 p.m.-4.45 p.m.).

"The Influence of Changing Markets and Technology on Engineering Decisions" by J. M. Kershaw (Monsanto Chemicals (Aust.) Ltd., Melbourne).

"Everyday Areas for Reducing Distribution Costs in the Process Industries" by O. Richter (Brambles Industries Ltd., Sydney).

"The Impact of Indigenous Oil and Gas on the Australian Process Industries" by R. Newton (Esso Chemicals Australia Ltd., Sydney).

"Australia's Strategic Sites for Integrated Industrial Processing" by R. H. Buchanan (R. H. Buchanan & Associates, Kingsford, N.S.W.).

(b) Sydney Sessions, Monday, 24th August, 9.45 a.m.-4.45 p.m.

(iii) **Evaluation Techniques** (9.45 a.m.-12.30 p.m.).

"Simulation for Management" by B. Wiggins (Data Card (Aust.) Pty. Ltd., N.S.W.).

"A Measurement of Venture Risk, Using Expected Values" by I. Doig (Dept. of Chemical Engineering, University of N.S.W., Sydney).

"Optimal Operation of a Chemical Process in the Face of Uncertainty" by D. Quon*, L. Biswanger and P. M. Reilly (Dept. of Chemical and Petroleum Engineering, University of Alberta, Edmonton, Canada).

"Choosing Between Theory and Experiment" by S. W. Churchill (Dept. of Chemical Engineering, University of Pennsylvania, Philadelphia, U.S.A.).

(iv) **Implementation** (1.30 p.m.-4.45 p.m.).

"Financing Projects in the Australian Process Industries" by K. J. Hedley (K. J. Headley and Co., Sydney).

"The Role of Consultants in Australia's Growing Process Industries" by G. Thomas*, J. Laurie and D. Spencer (Vallentine, Laurie & Davies, Sydney).

"The Australian Engineer Constructor—The Challenge of the 70's" by C. V. Holland and R. H. Scott* (John Holland Construction Group, Melbourne).

"Manpower for the Growing Australian Process Industries" by E. Barraclough (Eastern Nitrogen Ltd., Sydney).

Further details from: H. R. C. Pratt, Australian Academy of Science, Canberra City, Australia.

ANNOUNCEMENT

The VIth International Congress of Cybernetics, organised in Namur (Belgium) from 7th–11th September, 1970, was a most successful occasion. 175 addresses and papers appear on the programme. The authors are drawn from the scientific elite of 31 countries.

This success is the reward of the efforts made by the International Association of Cybernetics, since its inception in 1956, with the aim of extending the sphere of cybernetic thinking.

The Association published the proceedings of the five previous congresses: 1956, 1958, 1961, 1964, 1967 and edits, since 1958, a quarterly review: *Cybernetica*.

Abstracts of the papers of the VIth Congress are available. They can be supplied on payment of a sum of 500 Belgian francs (10 U.S. dollars). Subscriptions to the proceedings are now open also. The cost of the subscription is 1.800 Belgian francs provided that it is paid before 31st December, 1970. Publication is planned for January 1972. The contents promise a production of exceptionally high quality. All orders sent in after 31st December, 1970, will be charged at the rate of 2.500 Belgian francs (50 U.S. dollars).

The International Association for Cybernetics is open to all who are concerned with the development and applications of cybernetics. By becoming members, they take part in a trend of ideas which is at the very heart of modern science. The annual subscription is modest: 200 Belgian francs (4 U.S. dollars) for individual members—1.000 Belgian francs (20 U.S. dollars) for firms and institutions. Membership enables to benefit by considerable reductions in the price of publications.

Those who wish to become members of the Association, to receive the abstracts of the papers of the VIth Congress, to be subscribers to the proceedings of the VIth Congress or to obtain the previous publications are requested to write to the International Association for Cybernetics, Palais des Expositions, Place André Ryckmans—B. 5000 Namur (Belgique).

NOTICE FROM THE HONORARY SECRETARY

1. The Secretary, Dr. K. M. Beazley, asks that all correspondence for him be sent to his home address, which is:—

44 Brockstone Road,
Boscoppa,
St. Austell, Cornwall.

Telephone: St. Austell 5244, or during working hours St. Austell 2381, Extn. 10.

2. We are pleased to announce the formation of a sister society in Italy; the Società Italiana Di Reologica, whose Secretary is:—

Dr. P. Crovetto,
Via Padulli 12,
20147 Milano, Italy.

The Society intends to hold a conference in April 1971 (date to be arranged not to clash with the Aberystwyth meeting). Contributors from Britain will be welcome and should contact the Secretary.

APPENDIX

ITERATIVE NUMERICAL METHODS FOR SOME INTEGRAL EQUATIONS ARISING IN RHEOLOGY

by

G. Williams and R. I. Tanner

Division of Engineering

Brown University

Providence, R. I. 02912

April 1969

Appendix I: Capillary Viscometer Integral Inversion

The numerical inversion program is written in Fortran IV. 5 is the code used throughout for card-reader input and 6 for printer-output. These code numbers may have to be changed to accommodate the particular computer used.

The inversion scheme requires that N pairs of data points (τ_ω, F) ($F = -4Q/\pi R^3$) be read into the computer on punched cards, where N may be as small as 3 and as large as 30. (With slight modification to the program, N may be larger than 30.) Included in N is the first data point (0.0,0.0). For each data set to be processed the computer will read $N+1$ cards. Thus, if there are 3 data sets to be processed, the computer will read $3(N+1)$ cards. The first card read will contain the integer number N in its first two columns with all other columns blank. The integer number N must be right-justified in the first two columns of this card. The next N cards read will contain one pair (on each card) of data points (τ_ω, F) . These numbers must be floating-point (decimal) numbers including the first data point (0.0,0.0). The values of τ_ω must appear in columns 1 through 10, may be unequally spaced, and MUST be given in ascending order, while the values of F must appear in

columns 11 through 20. For example, if $\tau_\omega = 127.21$ and $F = -2162.1$ the data card will appear as follows:

1	2	7	.	2	1	-	2	1	6	2	.	1							
1				6			10	11				16						20	
Column																			
number																			

Decimal points must always appear in columns 6 and 16. (If the input data does not fit into the format outlined above, slight changes in the FORMAT statement [card 19] must be made.)

The N input values for F ($= -4Q/\pi R^3$) are stored in the first column of the array, $F(I,J)$, $1 \leq I \leq N$. Now the procedure is to guess systematically the values for $\gamma(I)$ and to test if these values, when integrated, give values of F , $F(I,J)$ equal to $F(I,1)$. For the first iteration, $\gamma(I,2) = -F(I,1)$, and for succeeding iterations,

$$\gamma(I,J+2) = \gamma(I,J+1) + \Delta\gamma(I,J+1),$$

$$\text{where } \Delta\gamma(I,J+1) = -0.25[F(I,1) - F(I,J+1)].$$

If $\text{SIGMA}(J+1)$, where

$$\text{SIGMA}(J+1) = \sum_{I=2}^N \left| \frac{F(I,1) - F(I,J+1)}{F(I,1)} \right|$$

is less than $0.005N$, the program will print the message "CONVERGENCE HAS BEEN ACHIEVED AFTER JJ ITERATIONS," where $JJ = J+1$; if $\text{SIGMA}(J+1) \geq \text{SIGMA}(J)$, the program will print "THE ITERATION PROCEDURE IS BEGINNING TO DIVERGE. THE BEST VALUES COMPUTED WILL NOW BE DISPLAYED."; and, if $\text{SIGMA}(98) \geq 0.005N$, the program will print "CONVERGENCE HAS NOT BEEN ACHIEVED AFTER 98 ITERATIONS." After printing one of the above messages, the program will then print the current value of $\text{SIGMA}(J+1)$ and the current values of the variables $\gamma(I,JJ)$, $F(I,JJ)$, $\Delta\gamma(I,JJ)$, JJ , and $\eta_s(I) = \tau_\omega(I)/\gamma(I,JJ)$, where η_s is the steady shearing viscosity in poises, if τ_ω is in dyn-cm⁻² and γ is in sec⁻¹. The maximum number of iterations is 98. If $\text{SIGMA}(J+1) \geq \text{SIGMA}(J)$, JJ will equal J .

The function subprogram TIGER, which performs the numerical integration, is based on overlapping parabolas. It combines both an integrating and a smoothing feature. Two quadratic polynomials are fitted (to the function $\gamma(\tau)$) over three consecutive points: the first polynomial, $P_1(\tau)$, over the points τ_{i1} , τ_{-i} , and τ_{i+1} , and the second, $P_2(\tau)$, over the points τ_i , τ_{i+1} , and τ_{i+2} . Then the area between the points τ_i and τ_{i+1} is equal to

$$\frac{1}{2} \int_{\tau_i}^{\tau_{i+1}} \tau^2 [P_1(\tau) + P_2(\tau)] d\tau.$$

There is no smoothing over the first and last intervals. Further details are given by Davis and Rabinowitz.

A flow chart for this program is presented in Figure 1.

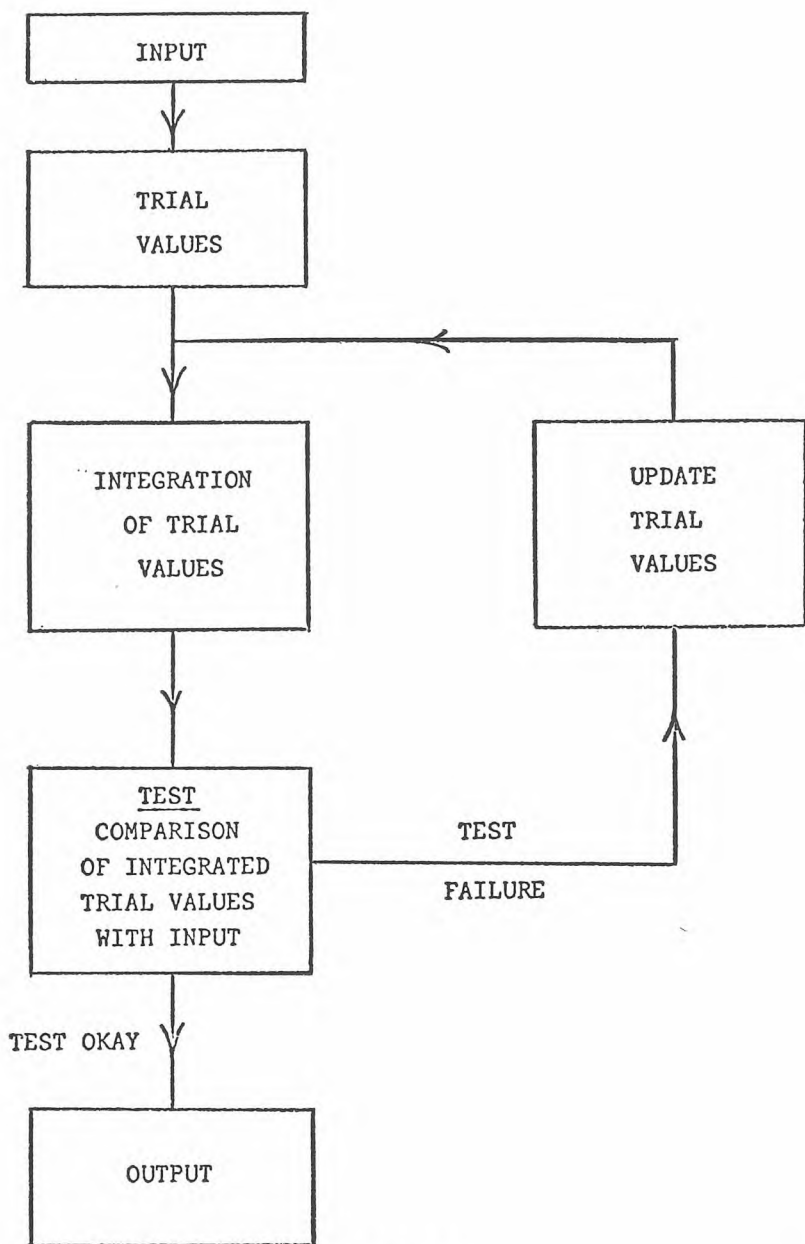


Figure 1.

Ref. P. J. Davis and P. Rabinowitz, *Numerical Integration* (Blaisdell, Massachusetts, 1967).

Capillary Viscometer Integral Inversion Program

```

1      DIMENSION X(30),Y(30),TAUW(30),F(30,100),
      GAMDOT(30,100),1DELGAM(30,100),DELF(30,100),
      SIGMA(100)
2  9188  CONTINUE
3      DO 12 I = 1,30
4      DO 12 J = 1,100
5      X(I) = 0.0
6      Y(I) = 0.0
7      TAUW(I) = 0.0
8      F(I,J) = 0.0
9      SIGMA(J) = 0.0
10     GAMDOT(I,J) = 0.0
11     DELF(I,J) = 0.0
12  12    DELGAM(I,J) = 0.0
13     READ(5,66)N
14  66    FORMAT(12)
15     XLO = 0.0
16     EPP = 0.25
17     DO 88 I = 1,N
C      THE MAXIMUM NUMBER OF INPUT DATA
      POINTS IS 30
C      THE X(I) MAY BE UNEQUALLY SPACED BUT
      MUST BE GIVEN IN ASCENDING ORDER
18     READ(5,22)X(I),F(I,1)
19  22    FORMAT(2F10.4)
20     TAUW(I) = X(I)
21     GAMDOT(I,2) = -F(I,1)
22     Y(I) = GAMDOT(I,2)
23  88    CONTINUE
24     DO 59 J = 1,98
25     DO 59 I = 2,N
26     XUP = TAUW(I)
27     Y(I) = GAMDOT(I,J+1)
28     NN = N
29     FACTOR = (-4./(TAUW(I)*TAUW(I)*TAUW(I)))
30     F(I,J+1) = FACTOR*TIGER(X,Y,NN,XLO,XUP)
31     DELGAM(I,J+1) = -EPP*(F(I,1)-F(I,J+1))
32     GAMDOT(I,J+2) = GAMDOT(I,J+1)+
      DELGAM(I,J+1)
33     DELF(I,J+1) = F(I,1)-F(I,J+1)
34     JJ = J+1
35     IF (I-N)59,72,72
36  72    CONTINUE

```

```

37      TOTNUM = 0.0
38      DO 86 KI = 2,N
39  86    TOTNUM = TOTNUM + ABS(DELF(KI,J+1)/
        F(KI,1))
40      SIGMA(J+1) = TOTNUM
41      SIGMA(1) = 100.0
42      IF(SIGMA(J+1) - SIGMA(J))226,1502,1502
43  226    CONTINUE
44      EPSILO = 0.005*N
45      IF(TOTNUM - EPSILO)727,59,59
46  59    CONTINUE
47      CONVER = TOTNUM
48      WRITE(6,921)
49  921    FORMAT(' CONVERGENCE HAS NOT BEEN
        ACHIEVED AFTER 98 ITERATIONS. ')
50      GO TO 1609
51  1502    CONTINUE
        JJ = JJ - 1
52      WRITE(6,5207)
53  5207    FORMAT(' THE ITERATION PROCEDURE IS
        BEGINNING TO DIVERGE. THE BES IT VALUES
        COMPUTED WILL NOW BE DISPLAYED. ')
54  1609    CONTINUE
55      WRITE(6,922)SIGMA(JJ)
56  922    FORMAT(1X,E15.6//)
57      GO TO 691
58  727    CONTINUE
59      WRITE(6,923)
60  923    FORMAT(' CONVERGENCE HAS BEEN
        ACHIEVED AFTER JJ ITERATIONS. ')
61      CONVER = TOTNUM
62      WRITE(6,124)CONVER
63  124    FORMAT(1X,E15.6//)
64  691    CONTINUE
65      WRITE(6,924)
66  924    FORMAT(' TAUW(I) GAMDOT(I,JJ) F(I,JJ)
        DELGAM(I1,JJ) JJ F(I,1) ')
67      DO 612 KNL = 1,N
68      WRITE(6,927) TAUW(KNL),GAMDOT(KNL,JJ),
        F(KNL,JJ),DELGAM(KNL,JJ),1JJ,F(KNL,1)
69  927    FORMAT(1X,4E15.6,I10,E15.6/)
70  612    CONTINUE
71      WRITE(6,23)
72  23    FORMAT(' I GAMDOT(I,JJ) ETAS TAU
        1W(I) ')
73      DO 6120 IX = 2,N
74      I = IX
75      ETAS = TAUW(IX)/GAMDOT(IX,JJ)

```

✓

```

76      WRITE(6,241)I,GAMDOT(IX,JJ),ETAS,TAUW(IX)
77  241  FORMAT(1X,I5,3E20.6/)
78  6120  CONTINUE
79      GO TO 9188
80      END
81      FUNCTION TIGER(X,Y,NN,XLO,XUP)
82      DIMENSION X(NN),Y(NN)
83      SUM = 0.0
84      SYL = XLO
85      J = NN
86      1B = 2
87      DO 1 I = 1,NN
88      IF (X(I) - XLO)1,17,17
89  1      IB = IB + 1
90  17      DO 2 I = 1,NN
91      IF (XUP - X(J))2,18,18
92  2      J = J - 1
93  18      J = J - 1
94      IF (IB - (NN - 1))81,81,52
95  52      IB = NN - 1
96  81      CONTINUE
97      IF (IB - J)96,96,13
98  13      J = IB
99  96      CONTINUE
100      DO 3 JM = IB,J
101      X1 = X(JM - 1)
102      X2 = X(JM)
103      X3 = X(JM + 1)
104      TERM1 = Y(JM - 1)/((X1 - X2)*(X1 - X3))
105      TERM2 = Y(JM)/((X2 - X1)*(X2 - X3))
106      TERM3 = Y(JM + 1)/((X3 - X1)*(X3 - X2))
107      A = TERM1 + TERM2 + TERM3
108      B = -(X2 + X3)*TERM1 - (X1 + X3)*TERM2 -
          (X1 + X2)*TERM3
109      C = X2*X3*TERM1 + X1*X3*TERM2 + X1*X2*
          TERM3
110      IF (JM - IB)14,4,14
111  4      CA = A
112      CB = B
113      CC = C
114      GO TO 15
115  14      CA = 0.5*(A + CA)
116      CB = 0.5*(B + CB)
117      CC = 0.5*(C + CC)
118  15      SYU = X(JM)
119      SUM = SUM + CA*(SYU**5 - SYL**5)/5. + CB*.25*
          (SYU**4 - SYL**4)1 + CC*(SYU**3 - SYL**3)/3
120      CA = A

```


The N input values for Ω are stored in the first column of the array $\Omega(I,J), \Omega(I,1), 1 \leq I \leq N$. Now the procedure is to guess systematically the values for $\gamma(I)$ and to test if these values, when integrated, give values of $\Omega, \Omega(I,J)$ equal to $\Omega(I,1)$. For the first iteration, $\gamma(I,2) = 8.6\Omega(I,1)$, and for succeeding iterations,

$$\gamma(I,J+2) = \gamma(I,J+1) + \Delta\gamma(I,J+1),$$

$$\text{where } \Delta\gamma(I,J+1) = \Omega(I,1) - \Omega(I,J+1).$$

If $\text{SIGMA}(J+1)$, where

$$\text{SIGMA}(J+1) = \sum_{I=1}^N \left| \frac{\Omega(I,1) - \Omega(I,J+1)}{\Omega(I,1)} \right|$$

is less than $0.005N$, the program will print the message "CONVERGENCE HAS BEEN ACHIEVED AFTER JJ ITERATIONS," where $JJ = J+1$; if $\text{SIGMA}(J+1) \geq \text{SIGMA}(J)$, the program will print "THE ITERATION PROCEDURE IS BEGINNING TO DIVERGE. THE BEST VALUES COMPUTED WILL NOW BE DISPLAYED."; and, if $\text{SIGMA}(98) \geq 0.005N$, the program will print "CONVERGENCE HAS NOT BEEN ACHIEVED AFTER 98 ITERATIONS." After printing one of the above messages, the program will then print the current value of $\text{SIGMA}(J+1)$ and the current values of the variables $\gamma(I,JJ), \Omega(I,JJ), \Delta\gamma(I,JJ), JJ$, and $\eta_s(I) = \tau_R(I)/\gamma(I,JJ)$, where η_s is the steady shearing viscosity in poises, if τ_R is in dyn-cm^{-2} and γ is in sec^{-1} . The maximum number of iterations is 98. If $\text{SIGMA}(J+1) \geq \text{SIGMA}(J)$, JJ will equal J .

The function subprogram AVINT, which performs the numerical integration, is identical to the integration routine TIGER (described in Appendix I), with the exception that the quadratic polynomials are fitted to the function $\gamma(\tau)/\tau$. A flow chart for this program is presented in Figure 1.

Concentric Cylinder Viscometer Integral Inversion Program

```

1      DIMENSION X(30),Y(30),TAUR(30),OMEGA(30,100),
      GAMDOT(30,100),1DELGAM(30,100),
      DOMECA(30,100),SIGMA(100),XLIM(30),RPM(30)
2  9188  CONTINUE
3      DO 12 I = 1,30
4      DO 12 J = 1,100
5      X(I) = 0.0
6      Y(I) = 0.0
7      TAUR(I) = 0.0
8      OMEGA(I,J) = 0.0
9      SIGMA(J) = 0.0
10     GAMDOT(I,J) = 0.0
11     DOMECA(I,J) = 0.0
12     DELGAM(I,J) = 0.0
13     XLIM(I) = 0.0
14  12   RPM(I) = 0.0

```

```

15      READ(5,66)N
16 66    FORMAT(I2)
17      PI = 3.14159
18      EPP = 1.0
19      DO 88 I = 1,N
C      THE MAXIMUM NUMBER OF INPUT DATA
        POINTS IS 30
C      THE X(I) MAY BE UNEQUALLY SPACED BUT
        MUST BE GIVEN IN ASCENDING ORDER
20      READ(5,22)S,RPM(I),TAUR(I)
21 22    FORMAT(F10.5,F20.5,F10.4)
22      X(I) = TAUR(I)
23      OMEGA(I,1) = (PI/30.)*RPM(I)
24      GAMDOT(I,2) = 8.6*OMEGA(I,1)
25      XLIM(I) = TAUR(I)*S*S
26      Y(I) = GAMDOT(I,2)/TAUR(I)
27 88    CONTINUE
28      DO 59 J = 1,98
29      DO 59 I = 1,N
30      XLO = XLIM(I)
31      XUP = TAUR(I)
32      Y(I) = GAMDOT(I,J+1)/TAUR(I)
33      NN = N
34      OMEGA(I,J+1) = 0.5*AVINT(X,Y,NN,XLO,XUP)
35      DELGAM(I,J+1) = EPP*(OMEGA(I,1) - OMEGA
        (I,J+1))
36      GAMDOT(I,J+2) = GAMDOT(I,J+1) + DELGAM
        (I,J+1)
37      DOMEGA(I,J+1) = OMEGA(I,1) - OMEGA(I,J+1)
38      JJ = J+1
39      IF (I - N)59,72,72
40 72    CONTINUE
41      TOTNUM = 0.0
42      DO 86 KI = 1,N
43 86    TOTNUM = TOTNUM + ABS(DOMEGA(KI,J+1)/
        OMEGA(KI,1))
44      SIGMA(J+1) = TOTNUM
45      SIGMA(1) = 100.0
46      IF (SIGMA(J+1) - SIGMA(J))226,1502,1502
47 226   CONTINUE
48      EPSILO = 0.005*N
49      IF (TOTNUM - EPSILO)727,59,59
50 59    CONTINUE
51      CONVER = TOTNUM
52      WRITE(6,921)
53 921   FORMAT(' CONVERGENCE HAS NOT BEEN
        ACHIEVED AFTER 98 ITERATIONS. ')
54      GO TO 1609

```

```

55 1502 CONTINUE
      JJ = JJ - 1
56      WRITE(6,5207)
57 5207 FORMAT(' THE ITERATION PROCEDURE IS
      BEGINNING TO DIVERGE. THE BES 1T VALUES
      COMPUTED WILL NOW BE DISPLAYED. ')
58 1609 CONTINUE
59      WRITE(6,922) SIGMA(JJ)
60 922  FORMAT(1X,E15.6//)
61      GO TO 691
62 727  CONTINUE
63      WRITE(6,923)
64 923  FORMAT(' CONVERGENCE HAS BEEN
      ACHIEVED AFTER JJ ITERATIONS. ')
65      CONVER = TOTNUM
66      WRITE(6,124) CONVER
67 124  FORMAT(1X,E15.6//)
68 691  CONTINUE
69      WRITE(6,924)
70 924  FORMAT(' TAUR(I) GAMDOT(I,JJ) OMEGA(I,JJ)
      DELGAM(I,1JJ) JJ OMEGA(I,1) ')
71      DO 612 KNL = 1,N
72      WRITE(6,927) TAUR(KNL), GAMDOT(KNL,JJ),
      OMEGA(KNL,JJ), DELGAM(KNL,JJ), 1JJ,
      OMEGA(KNL,1)
73 927  FORMAT(1X,4E15.6,I10,E15.6/)
74 612  CONTINUE
75      WRITE(6,23)
76 23   FORMAT(' I GAMDOT(I,JJ) ETAS TAU
      1R(I) ')
77      DO 6120 IX = 1,N
78      I = IX
79      ETAS = TAUR(IX)/GAMDOT(IX,JJ)
80      WRITE(6,241) I, GAMDOT(IX,JJ), ETAS, TAUR(IX)
81 241  FORMAT(1X,I5,3E20.6/)
82 6120 CONTINUE
83      GO TO 9188
84      END
85      FUNCTION AVINT(X,Y,NN,XLO,XUP)
86      DIMENSION X(NN),Y(NN)
87      SUM = 0.0
88      SYL = XLO
89      J = NN
90      IB = 2
91      DO 1 I = 1,NN
92      IF (X(I) - XLO) 1,17,17
93 1     IB = IB + 1
94 17    DO 2 I = 1,NN

```

```

95      IF (XUP - X(J))2,18,18
96  2    J = J - 1
97  18   J = J - 1
98      IF (IB - (NN - 1))81,81,52
99  52   IB = NN - 1
100  81   CONTINUE
101      IF (IB - J)96,96,13
102  13   J = IB
103  96   CONTINUE
104      DO 3 JM = IB,J
105      X1 = X(JM - 1)
106      X2 = X(JM)
107      X3 = X(JM + 1)
108      TERM1 = Y(JM - 1)/((X1 - X2)*(X1 - X3))
109      TERM2 = Y(JM)/((X2 - X1)*(X2 - X3))
110      TERM3 = Y(JM + 1)/((X3 - X1)*(X3 - X2))
111      A = TERM1 + TERM2 + TERM3
112      B = -(X2 + X3)*TERM1 - (X1 + X3)*TERM2
          -(X1 + X2)*TERM3
113      C = X2*X3*TERM1 + X1*X3*TERM2 + X1*X2*
          TERM3
114      IF (JM - IB)14,4,14
115  4     CA = A
116      CB = B
117      CC = C
118      GO TO 15
119  14    CA = 0.5*(A + CA)
120      CB = 0.5*(B + CB)
121      CC = 0.5*(C + CC)
122  15    SYU = X(JM)
123      SUM = SUM + CA*(SYU**3 - SYL**3)/3. + CB*.5*
          (SYU**2 - SYL**2) + CC*(SYU - SYL)
124      CA = A
125      CB = B
126      CC = C
127  3     SYL = SYU
128      AVINT = SUM + CA*(XUP**3 - SYL**3)/3. + CB*.5*
          (XUP**2 - SYL**2) + CC*(XUP - SYL)
129      RETURN
130      END

```

BRITISH SOCIETY OF RHEOLOGY

Computer Program Catalogue Publication Abstract

1. Author
2. Establishment
.....
..... Tel. No.
3. Program Abstract
.....
Input Data
.....
Output Data
4. Program date
.....
5. Language
.....
6. Computer requirements
.....
.....
7. Type of Input/Output
.....
8. References
.....
.....
.....
9. Related programs
.....
10. Available for copy/data processing
.....
.....

Return to: Dr. J. Harris,
Postgraduate School of Chemical
Engineering,
University of Bradford,
Bradford 7, U.K.

Additional blank abstract sheets are available as required from the above address.

8

DIARY

1971

- 4-6 January.** Conference—Designing for Plastics; The Integrated Approach, at Cranfield. Plast. Inst.
- 2-4 February.** Conference—Carbon Fibres, their Composites and Applications. Plast. Inst.
- 16 February.** Conference—Bulk Handling. Plast. Inst./Inst. Mat's Hndlg.
- 10 March.** Conference—Plastics in Fire: Building. Joint Plast. Inst./Agreement Board.
- 11-12 March.** Conference—Plastics in Fire: Transport and Materials. Joint Plast. Inst./Agreement Board.
- 25-27 March.** Conference—Exploitation of Polymer Research at Loughborough. Joint I.R.I., Plast. Inst.
- 13-16 April.** Conference—Theoretical Rheology at Aberystwyth. Brit. Soc. Rheol.
- 22 and 23 April.** Conference—Industrial Conference at Leamington Spa. I.R.I.
- 15-18 May.** Conference—International Rubber Conference at Brighton. I.R.I.
- 29 August-2 September.** Symposium—International Symposium on Two-Phase Systems at Technion City, Haifa, Israel.
- 16-23 September.** Exhibition—6th International Plastics Trade Fair "K-71" at Dusseldorf.
- 20-23 September.** Conference—Annual Autumn B.S.R. Conference at Shrivenham, Wilts.

1972

6th Intn. Congress on Rheol. France 1972.

NOTICE TO INTENDING CONTRIBUTORS

The B.S.R. Bulletin is now available as a vehicle for several categories of communication by Members.

1. Technical papers (two copies required).
2. Descriptive papers of general interest.
3. Letters which may be either
 - (i) technical or
 - (ii) non-technical.

The technical papers will be refereed and so will technical letters but the latter only by one person. Descriptive and non-technical material will be published if it is of general interest.

In addition, project reports and computer information will be published.

It is hoped that B.S.R. members will find rapid publication sufficiently attractive to warrant submitting work.