

NOTICE TO INTENDING CONTRIBUTORS

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

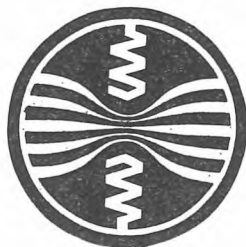
1. Technical papers (two copies required).
2. Descriptive papers of general interest.
3. Letters which may be either
 - (i) technical or
 - (ii) non-technical.

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.

BULLETIN



BRITISH SOCIETY OF RHEOLOGY

1971, No. 4, Vol. 14

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Hon. Editor:

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

FOREWORD

In rheology today there exists those people who accept the label "empirical" being attached to their work and who may to a certain extent feel self-conscious about it and others who are inclined to be somewhat harshly condescending in their attitude to this type of work. Such a divergence in mental attitude may arise as a result of a misunderstanding about the nature of empiricism, its place in human activity and its history, which is both long and distinguished by any standards.

The philosophical foundations of empiricism are to be found in the works of those eminent writers, Bacon and John Locke who published in the seventeenth century. More recently Einstein (A. Einstein, "Relativity", Methuen and Co. Ltd., 1962 reprint) talks about the *empirical* physical foundations of relativity. In the face of such associations, derogatory remarks about empiricism are, in general, more likely to reflect unfavourably on the person who utters them rather than on the subject.

There appears to be an idea abroad at the present time that if one takes an empirical formulation, then carries out some type of mathematical manipulation and arrives at a conclusion, then the result is "theoretical" or "semi-theoretical" and not to be confused with the much more lowly empirical type of treatment where one simply fits the data with a formula.

However, in science empiricism is ubiquitous as can be seen from the outline given elsewhere in this issue entitled "A Note on Empiricism".

COUNCIL 1971-72

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: DR. J. FERGUSON, Dept. of Fibre Science,
Univ. of Strathclyde, Glasgow.

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. NEUMAN, DR. P.
SHERMAN, DR. K. WALTERS.

1970-71 COUNCIL, VICTORIA 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. DICKSON, 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.

ANNUAL REPORTS

REPORT OF THE SECRETARY

The past year has again been a fairly active one for the Society. Matters such as finance, membership and publications will be dealt with separately by the officers concerned; I shall merely gather up the fragments that remain and try to make a small loaf from them.

1. Conferences

Two major conferences organised by the Society have been held during this period. September of last year furnished a three-day meeting on "Rheology in Industry" at the Royal Military College of Science, Shrivenham, which stressed the many ways in which rheology finds its niche in industry. In April of this year a very full programme on "Theoretical Rheology" was held at the University College of Wales, Aberystwyth, and Dr. Walters and Dr. Pearson are to be thanked for fulfilling a long felt want so magnificently. By any normal criteria, both conferences can be judged successful, with attendances in both cases of well over 100.

The present meeting, here at Exeter, is a departure in one way from our usual conference practice in that it has no specific subject as title. Comments on this conference, and constructive criticism in particular, will be welcomed by the Secretary. Suggestions for topics for future conferences would also be gratefully received.

As far as future meetings are concerned, the main one will be the International Congress at Lyon, France, 4th to 8th September, 1972. The Secretariat has issued a call for papers, which has been circulated to members. Since this conference would clash with any major conference we ourselves might have, it has been decided to hold a restricted meeting next autumn; a title of "Rheology and the Environment" has been suggested, and it is hoped to invite a major speaker from the Lyon meeting to address us. Other meetings to be noted are a joint meeting on the rheology of lubricants (with the Society as a participating body) to be held on 6th-7th July, 1972, probably at Nottingham. Between 26th and 29th March, 1973, a joint meeting on yield, deformation and fracture of polymers (sponsored by the Plastics Institute, again with participation by ourselves) is to be held at Churchill College, Cambridge. (Technical Secretary: Dr. P. Bowden, Dept. of Metallurgy, Pembroke St., Cambridge.)

2. Liaison

Relations with other Societies have been maintained at their usual cordial and fruitful level. One matter in particular has been the source of some correspondence—namely, the possible establishing by the Society of a second major European rheological journal. For some time, disquiet has been expressed at the length of time taken

for papers submitted to "Rheologica Acta" to appear in print. The opinion of other European Societies was sought as to the advisability of starting a second journal, in an attempt to overcome these shortcomings. The replies, though not wholly unfavourable, suggested that we should approach the Editor of "Rheologica Acta" directly, to see whether some improvement in the arrangements for publishing English Language papers might not be achieved, possibly by the appointment of a second executive editor. We have not yet received a reply from the Editor.

The Secretary now holds copies of the Journal of Mechanics of the Polish Academy of Science, Krakow, to which members are welcome to refer.

3. New South Wales Branch

Of our two Australian Branches, the Victoria Branch is flourishing, while the New South Wales is virtually dead. Your Council are proposing that the NSW Branch be wound up and you will be asked to consider this matter later in this Meeting.

4. Research Committee

Several times at Council Meetings, the usefulness of the Research Committee has been called into question. Apart from acting as adjudicator for the Gold Medal Competition, this body currently appears to have very little useful work to do. It was felt that an *ad hoc* committee would cover the needs of the Gold Medal Competition, and your Council is to propose to you that the Society's Constitution be amended to allow the Research Committee to be disbanded.

5. Gold Medal Competition

Your Council proposes that the scope of this competition (next to be held in 1973) should be widened to accept distinguished work on the theory and application of rheology, and that a less "distinguished" award be made at regular intervals. An award might, for instance, be made for a significant *paper*.

If the Research Committee should be disbanded, we suggest that a small panel (say, three) past Presidents should be empowered to make recommendations once a year to Council regarding possible recipients of such awards.

6. B.S.I. Glossary Committee

The Society is represented on the British Standards Institution Committee, which is currently preparing a Glossary of Rheological Terms. A draft of the completed glossary should be available in the foreseeable future.

7. Working Parties and Classification Schemes

As is well known, the Society together with the Institution of Chemical Engineers set up a Joint Working Party which produced a Classification Scheme on the rheology of fluids. A second J.W.P. was subsequently established to deal similarly with solids. Subsequent experience and enquiry have shown that very little use was being, or would be, made of the Fluids scheme; further, not all abstractors for *Rheology Abstracts* were prepared to classify their abstracts in this way. Council have therefore taken the following steps:

- (a) Preparation of a complete set of punched cards relevant to the fluids scheme has been suspended.
- (b) The Solids working party, having taken its work to the Report stage, has been asked to submit its report without further refinement.

It should be noted that in neither case has the work of these Working Parties been thrown on the scrap heap, but there is considerable evidence to suggest that little use will be made of it. The reports are nevertheless in existence, and the possibility of a combined representative system has been suggested.

DR. K. M. BEAZLEY.
September 1971.

REPORT OF THE HONORARY TREASURER

As is clear from the appended accounts the expenditure of the Society exceeded income for the year by £140.96. The deficit arose primarily through a drop in our share of the profits from *Rheology Abstracts* to £550 from about £890 in each of the previous two years. There is every prospect that our share of profits in the next financial year will be even smaller since costs have risen but the subscription for non-members to *Rheology Abstracts* has remained at £12 p.a. The deficit for the year would have been much greater if expenditure (other than that associated with conferences) had not fallen by £240 compared with the previous year. Expenditure under several headings was less, due partly to chance factors, but we cannot rely on a continuation of these levels. If expenditure had been at the level of 1969-70 the deficit would have been £381.

For several years income from *Rheology Abstracts* has exceeded income from all other sources together and the financial health of the Society has in consequence been critically dependent on this source of income. Your Council is actively considering ways of reducing expenditure but under present inflationary conditions it will be difficult to prevent expenditure rising above its present level without materially reducing the activities of the Society. Consequently your Council has regretfully decided to recommend an immediate increase to £2 in the annual subscription, except for members of the Australian Branch. This is the first increase since 1945 and since most members are now able to claim income tax relief on the subscription the net cost of membership in future will be only about 50% above the 1945 level.

At the time of the formation of the Australian Branches several years ago Council decided to ask for only a token subscription to the parent Society (25p per member) in order to do everything possible to encourage the new Branches. This amount does not cover postage and run-on costs for publications and it is proposed that Australian members should pay a subscription of £1.50 to the parent Society from October 1972. This is less than the proposed subscription for other members since members in Australia pay an additional amount to the Branch to support local meetings, administration, etc. The increase is deferred to 1972 since it is not practicable to inform these members of the increase by 1st October this year.

Finally I should like to emphasise that the Society still relies heavily on the income from *Rheology Abstracts* and that the Editor and his team of abstractors not only provide a valuable service to members but also provide this income. Any offers to share the load of abstracting will be very welcome.

R. W. WHORLOW, Hon. Treasurer.

September 1971.

BRITISH SOCIETY OF RHEOLOGY

Balance Sheet as at 30th June 1971

ASSETS

Brentwood U.D.C. 9½% Bond	...	...	...	...	1500.00
Debtors	...	...	...	...	623.01
Cash at Lloyds Bank Ltd.	...	...	...	...	
Deposit Account	...	...	...	...	696.89
Current Account	...	...	...	...	12.66
					709.55
					2,832.56

Less

CURRENT LIABILITIES

Sundry Creditors	...	...	...	...	...	25.00

NET ASSETS	...	...	...	...	...	...	£2807.56
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Represented by:—

GENERAL FUND

As at 1st July 1970	...	...	...	...	...	2948.52
Deduct: Excess of	Expenditure	over	Income	for		
the year	...	...	...	...	...	140.96
						£2807.56

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.
6th September 1971.

Revenue Account for the year ended 30th June 1971

EXPENDITURE

Committee Expenses (mainly travel):—			
161	Council	312.05	
164	B.S.I. Committee	107.53	
37	Publications Working Party	10.53	
	Solids Working Party	8.80	
	British National Committee on Materials	6.04	
			444.95
458	Bulletin—Production Costs		504.30
166	Abstracts—Production Costs		112.95
Expenditure by Officers:—			
	Secretary	41.37	
	Treasurer	15.62	
504	Membership Secretary	246.15	
			303.14
119	Gold Medals		105.15
30	Professional Fees		25.00
21	General Expenses		7.77
			1503.26

INCOME

511	Annual Subscriptions and Entrance Fees	596.92	
884	Publisher—Rheology Abstracts	550.40	
3	Bulletin Subscription	1	
Investment Income—gross:—			
	Bank Deposit Interest	42.12	
174	Brentwood 9½% Bond	142.50	
			184.62
Conferences—net income:—			
	Shrivenham 1970	19.35	
	Aberystwyth 1971	72.80	
			92.15
Deduct: Expenditure incurred for future conferences:—			
	Exeter 1971	55.00	
	Lubricants 1972	7.79	
			62.79
135			
			29.36
			£1362.30
35	Excess of Expenditure over Income for the Year ...		£140.96

REPORT OF THE MEMBERSHIP SECRETARY

Membership of the Society now stands at 593, comprising:

398 Home Members

117 Foreign Members

78 Australian Members.

Since 28th September 1970 we have elected 34 new Members. We have however been notified of 13 voluntary resignations, and there have been 56 "enforced" resignations.

At this meeting we are hoping to introduce a new scheme whereby subscriptions are paid via Credit Transfer from the Member's Bank to the Society's Bank. May I emphasise the usefulness of this arrangement where Members are not intending to pay by Bankers Order.

39 Members are currently in arrears for 1970/71 subscriptions, and this may explain apparent discrepancies between Honorary Treasurer's Report of income and the stated Membership of the Society.

R. R. ADDIS, September 1971.

REPORT OF HONORARY EDITOR RHEOLOGY ABSTRACTS

The amount of information contained in *Rheology Abstracts* continues to increase: in the period September 1970 to September 1971 a total of 903 articles in the literature have been covered, together with 41 abstracts of papers given at the Society's conferences, and five book reviews. The whole was as usual co-ordinated by an author index and a comprehensive subject index, the latter painstakingly compiled once more by Dr. Mardles.

Although all principal journals are now covered I am aware that some specialised fields do not receive the attention that they deserve. I should therefore be glad to hear suggestions for further journals which might be included. Did an abstract of your last paper duly appear in R.A.?

In view of the limited use which is being made of the fluids classification scheme, less abstracts will be classified for the time being, and the complementary solids classification scheme is to be held in abeyance. However, for the benefit of those who wish to search the recent literature quickly, a set of punched cards has been prepared at Swansea. Our thanks are due to Dr. Nebrensky, and Mr. Neelakantan who have carried out this arduous task. In due course, when each issue of Abstracts has grown to several times its present size, we may find a pressing need for classification in which case schemes to cover the whole of Rheology will be immediately available.

Once again let me express thanks on behalf of the Society to the 28 Members who have consistently provided abstracts throughout the year. In order to maintain the present coverage several abstractors perform an almost Herculean task, and indeed have done so for many years, so I should be particularly glad to hear from any other members who have access to primary journals who would be willing to devote a few hours per annum to this essential service.

List of Abstractors 1970-1971

Mr. D. M. Bancroft (Welwyn)
Dr. H. A. Barnes (Port Sunlight)
Dr. K. M. Beazley (St. Austell)
Dr. C. E. Chaffey (Canada)
Dr. C. F. Chan Man Fong (Reading)
Dr. M. F. Culpin (Pontypool)
Mr. C. B. Duckham (Salford)
Dr. J. Ferguson (Strathclyde)
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)
Mr. P. Langborne (N.E.L.)
Mr. R. S. Lenk (South Bank)
Dr. F. M. Leslie (Strathclyde)
Dr. J. Nebrensky (Swansea)
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. R. Roscoe (Newcastle)
Mr. G. R. Sothorn (Brunel)
Dr. K. Walters (Aberystwyth)

A. EVANS, September 1971.

REPORT OF THE EDITOR OF THE BULLETIN

The present function of the *Bulletin* is to provide a vehicle for information of items with a rheological flavour for the Members of the Society. It finds a niche beside *Rheology Abstracts* and the multitude of other journals which those with active scientific instincts are constrained to read. This journal therefore plays a role which is analogous in many respects to those published by other scientific bodies; in the actual event the physical form is not quite like that of any other publication.

Within the constraints of available material and Society policy the *Bulletin* crystallizes as a compact publication which is subject to review on a cost/effectiveness basis. The range of material carried within the last twelve months has been rather large, as has been the case with the two previous volumes. The amount of material in any one category on the other hand has been rather small, the fourth number in any volume is distended by the inclusion of annual reports. Apart from these reports a useful flow of material has occurred which has added to the effectiveness of the *Bulletin* and also, unfortunately, to the costs. But likely contributors should not allow consideration of the latter factor to act as too much of a deterrent.

The Editor extends his grateful thanks on behalf of other Society members to those who have contributed in any way to the production of the *Bulletin* in the past twelve months.

DR. J. HARRIS, September 1971.

Working Party on the Classification of Rheological Research on Solids

REPORT

Origin and Aims

The Working Party on the Classification of Rheological Research on Solids was set up by the Research Committee of the British Society of Rheology in May 1968. Its conception has an origin in the Working Party on non-Newtonian Flow which was set up jointly by the Institution of Chemical Engineers and the British Society of Rheology in 1964. The purpose of this Joint Working Party was to survey the field of industrial applications involving non-Newtonian fluids and, as a means to that end, a system of classifying and retrieving information on the rheology of fluids was produced. (Details of which are given in the Joint Working Party Report on non-Newtonian Flow, published in *The Chemical Engineer*, January 1971, pp. 11-15.) Since 1968, the Fluids Classification System has been adopted for trial use in The British Society of Rheology journal, *Rheology Abstracts*. However, the system does not include solids and the present Working Party was therefore set up to produce a parallel Solids Classification System, with a view to its adoption in *Rheology Abstracts*.

Membership

The Working Party was constituted as follows:

Dr. J. P. Berry, Rubber and Plastics Research Association (Chairman).

Dr. A. T. J. Hayward, National Engineering Laboratory (Secretary from May 1968 to November 1968, Member from November 1968 to October 1970).

Mr. K. Lammiman, Esso Research Limited.

Mr. D. Murfin, British Ceramics Research Association.

Professor K. E. Puttick, University of Surrey.

Mr. B. Warburton, University of London.

Mr. A. Evans, Royal Victoria Infirmary (Editor, *Rheology Abstracts*; Co-opted Member since October 1970).

Dr. D. C-H. Cheng, Warren Spring Laboratory (Secretary since November 1968).

It should be commented that the membership of the Working Party contained a number of persons who would not claim to be experts in the rheology of solids. But they were members of the Joint Working Party and were therefore included to ensure that the Solids Classification to be produced is compatible with the Fluids Classification already devised. Plans were made to enlarge the membership to cover different specific areas of solid interests, but it was agreed that a draft of the Solids Classification should first be prepared before the plans were executed.

Programme of Work

The programme of work was conceived as follows:

- (a) A sub-committee of two members to make a very tentative first draft of the Classification.
- (b) The Working Party to discuss this draft and modify it.
- (c) Each member to try to use the modified Classification system.
- (d) The Working Party to make further modifications to the Classification in the light of members' experience in using it. After this further trial use and modification of the draft Classification were envisaged until a final Classifications system was agreed upon. Then
- (e) A sub-committee of two members to prepare a Cross Index and design a Punch Card.
- (f) The Working Party to approve the Cross Index and Punch Card and, lastly, to prepare the final Report.

In the course of events, the first draft of the Classification was prepared and modified. It was then put to use by each member individually attempting to classify the solids abstracts in *Rheology Abstracts*, vol. 11, Nos. 1 to 4, 1968. On comparing the results of the exercise, it became apparent that there were some important omissions from the draft Classification.

While further modifications were being made, it was decided that the sub-committee on Cross Index should be set up before the modification of the Classification. The sub-committee examined the entries in the subject index in *Rheology Abstracts* volumes 9 to 11, 1966–1968 and drew up, in effect, a thesaurus of terms, which were then matched against the draft Classification. As a result still further modifications were suggested.

At a full Working Party meeting, the draft Classification and the draft Cross Index were finalised. The layout of the Punch Card were also discussed.

The Classification System and Cross Index

The Classification and Cross Index as finally agreed are attached to this Report. The basic philosophy behind the Solids Classification system is the same as that for the Fluids Classification which has been discussed in *Rheology Abstracts*, 1968, *II*, 1–4 and *The Chemical Engineer*, April 1968, 86–88. The mechanism for using the system is also given.

It was considered that before the Solids Classification is adopted for use in *Rheology Abstracts*, it requires to be combined and/or rationalised with the Fluids Classification. Recommendations as to how this can be done will be made later on in this Report. Because of this, the numbering of the Solids Classification and the Cross Index was not finalised.

The Punched Card

The layout of the Punched Card was considered by the Working Party starting with the premise that there should be a separate card for the Solids Classification, possibly of a distinct colour to that of the Fluids Classification, and that the layout of the Solids Card should be as close as possible to that of the Fluids Card. The task proved to be somewhat difficult because it was thought inadvisable to reduce the number of categories in the Solids Classification to less than 75, which was six in excess of the 69 of the Fluids Classification. Although there are additional holes on the Punch Card that will accommodate the extra Solids categories, it may mean printing on the reverse side of the card if the existing layout on the Fluids Card is to be preserved. An alternative to the double-printing would be to exclude the B Language Categories from the Punched Card but this would mean that the layout of the existing Fluids Punched Card would have to be modified if uniformity is to be maintained.

No definite conclusion was arrived at by the Working Party. It was, however, considered that the situation cannot be properly resolved until the question of the combination and/or rationalisation of both the Solids and Fluids Classification systems is also carried out. The Report will return to this point below.

Recommendations

It is difficult for the Working Party to make definite recommendations on the future development of the Solids Classification and its use in *Rheology Abstracts*, because there is some doubt as regards the applicability and continued use of the Fluids Classification.

Even if it should be decided that the use of the Fluids Classification in *Rheology Abstracts* be discontinued, the Working Party would recommend that the Solids Classification system should be published without further refinement, so that both it and the Fluids Classification system will be available to future generations of rheologists and information scientists.

If it should be decided that the Fluids Classification be continued in use, it would be logical to adopt the Solids Classification to complete the system as originally intended. Then, the Working Party would recommend that the two Classifications should be combined and rationalised into an integral system. For example, it may be possible to devise a numbering scheme whereby the categories common to both the Solids and Fluids Classifications would be assigned the same numbers. The class of semi-solid materials appears, as such or otherwise, in both Classifications and it would be profitable to devote some thought on the unification.

The problem of the layout of the Punched Card, is considered by the Working Party to be linked up with the problems of the mechanism for using the Combined Classification system and of the promoting for the adoption of the system by a wide range of individual rheologists and organisations. Originally, separate Punch Cards were envisaged for the Solids and Fluids Classifications. With the suggested combination and rationalisation, some thought has to be spent on devising a new Punched Card.

Blank Punched Card, as available now for the Fluid Classification system, should also be made available as a way of promoting the use of the Classification system. The volume of sales would also serve as an indication of the usefulness of the Classification system.

Of more use would be to have completed Punched Cards, available with the actual references and abstracts printed on the reverse side and ready edge-punched either as an alternative and/or as a replacement of the existing bound volume of *Rheology Abstracts*. The Working Party believes that if this method is followed, there will be much wider use of the Classification system, Fluids and/or Solids. However, it is recognised that discussions will have to be held with the Publishers and that it may take some time before such a scheme is introduced.

It is outside the present terms of reference of the Working Party to consider the matters mentioned in the last four paragraphs in detail. Should the British Society of Rheology decide to adopt

the Solids Classification for use in *Rheology Abstracts* the Working Party would recommend that another study group should be set up to consider them further.

Conclusion

The Working Party has developed a Classification system for Rheological papers on Solids to parallel the Classification system for Fluids at present under trial in *Rheology Abstracts*. It is recommended that the Solids Classification should be published, in any event, so that both it and the Fluids Classification should be available to rheologists as information scientists. If the British Society of Rheology should decide to continue with the use of the Fluids Classification in *Rheology Abstracts* and to adopt the Solids Classification to complement it, it is recommended that further work should be carried out to combine and rationalise the two Classifications, to devise the mechanism of using the combined system and to consider methods of promoting the wider use of the system by rheologists.

19th April 1971.

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

University of Exeter

21st-23rd September, 1971

It was in excellent late summer weather which showed up the environs of Exeter University to advantage that the participants at the autumn B.S.R. Conference gathered after finding their way through some of the pleasing mysteries of the University site.

The University had its origins in the local demand for higher education following the great exhibition of 1851. A school of art was established in 1855 followed by the erection of a building in 1865 to house a country museum, library and school of art as a memorial to the Prince Consort. University extension lectures in this building prepared candidates for South Kensington science and arts exams. 1893 saw the extension of classes and Exeter Technical and University Extension College became in 1899 the Royal Albert Memorial College. London external degrees in 1901, the University College of S.W. England evolved in 1922 and finally in 1955 a royal charter founded the University of Exeter incorporating the University College.

No specific theme had been set down to restrict the submissions of papers to the Conference and this enabled a pleasing variety of topics to be presented. This variety had no detrimental effect on the Conference. In fact the interest of the audience is probably more

easily maintained over hours of patient listening by a frequent switch of subject-matter.

The first paper of the Conference was, "The viscoelastic properties of printing inks" by G. A. Lewis and A. J. B. Spaul, in which some of the transient effects to be found in these materials was discussed. In oscillatory tests it was found that the alkyd resin vehicle properties predominate. A time-temperature superposition was found for the results and a relaxation spectrum based on a second-order method of Williams and Ferry deduced from the data.

This was followed by "Some developments in the study of thixotropic behaviour" by D. C. H. Cheng. The "structural theory" of thixotropy developed in previous papers by Cheng and Evans was used as the basis of a discussion of flow conditions of industrial interest and also to propose that steady shear behaviour could be described by a non-linear viscoelastic equation.

In oscillatory pipe flow the velocity profiles differ from those in steady laminar motion and a range of experimental results of displacement (or velocity) profiles together with the associated phase angles was shown by R. Maheshwari and J. Harris in a paper entitled, "Amplitude and phase profiles in oscillatory tube flow". New apparatus for phase measurement was also described in this work.

"External flow of viscoelastic liquids through small orifices" was the title of a paper by D. R. Oliver and R. Bragg. In this paper experimental results obtained by ejecting several different liquids through fine bore orifices were reported. Some remarkably high thrusts being observed for very dilute (1 ppm) polymer solutions.

"The anisotropy of creep behaviour in oriental thermoplastics" was one of the few papers on solids presented at this conference. In it, D. W. Saunders and M. W. Darlington outlined the adaptation of classical elasticity theory to the more general field of time-dependent, anisotropic materials. Experiments were also reported on the simultaneous measurement of lateral and longitudinal strains during uniaxial creep.

An interesting recent addition to the instrumentation available in rheometry is the "balance rheometer". This apparatus subjects the material under test to periodic shearing motion but in an ingenious way the forces in a fixed reference frame are made stationary. An exposition of the application of this device was given by F. Assioma and A. Kepes in a paper entitled, "Dynamic mechanical properties of polyethylene melts determined by a balance rheometer". The angle of tilt determines the strain amplitude in this machine and it was not clear whether this would affect the properties of the test material to any significant effect by introducing a non-linear response. This would greatly complicate the analysis.

Another device for undertaking the same work was described in the paper, "Interpretation of experimental results from a new rheometer" by J. M. Broadbent and K. Walters. This apparatus is an eccentric cylinder device in which both cylinders possess the same rate of rotation, and cause alternate stretching and squashing of the test material. End effects and discrepancies in speed between cylinders are important in the interpretation of results.

Possibly the first paper ever given to a B.S.R. Conference by workers in South Africa was that entitled, "Secondary flows about a sphere and a disc rotating in an elasto-viscous liquid" by E. K. Cairncross and G. S. Hanford. Theoretical and experimental results were compared and the comparison was found to be fairly good at the equator but less satisfactory elsewhere.

"Effects of changes of surface tension and contact angles on normal force measurement with the Weissenberg rheogoniometer" was the title of the paper by J. F. Hutton. Note was made of the fact that alignment of platens, secondary flows and inertia are all problems in the measurement of normal force. In addition surface tension forces may be a cause of error; variations in normal force associated with change in iniquid contact angle at the platen perimeter were investigated.

Piezo-electric transducers applied to thrust and torque measurement in a Weissenberg rheogoniometer were described by R. W. Higman in a paper entitled, "A new torque and normal thrust measuring system for the Weissenberg rheogoniometer". Amongst the advantages claimed for this arrangement is the elimination of air bearing and cantilever system for normal force measurement, also the servo-nulling assembly. A comparatively high natural frequency (25 K Hz) was claimed as an additional advantage.

The last paper of the Wednesday session was by D. C. H. Cheng and K. G. Laws entitled, "New developments in parallel plate rheometry for the study of pastes". Apparatus and theory were described for the characterization of time-independent, high viscosity materials in a compression rheometer. Tests were conducted in an Instron tension/compression machine in which the platen faces approach each other at constant speed. Edge effects were eliminated by a guard ring.

A welcome break was provided by the Wednesday afternoon tours and the Conference Dinner at which the guest of honour was Professor G. K. T. Conn, Exeter University. Refreshed by this interlude the participants prepared for the final session.

In an exhaustive study of "Viscosity/concentration relations in deflocculated kaolin suspensions" K. M. Beazley reported the results of viscometric measurements on a wide range of kaolin clay suspensions. A Mooney type of equation with two friction factors and two packing

factors appeared to fit the viscosity data quite well. At high solids concentration the material was dilatant, but at lower concentrations shearing thinning occurred. An alternative type of correlation was confirmed over a wide range of solids concentration, showing a relationship between the root reciprocal of slurry viscosity and weight concentration.

The paper by L. A. Adorjan, "A rotational surface viscometer" described an instrument with several novel features. The non-plane surface of an interface adjacent to a solid surface can provide an awkward encumbrance when analysing surface viscosity measurement. This was overcome by the introduction of grooves into which the fluid surface fitted giving the desired plane surface in a Couette type of geometry. Some experimental results were also shown; they indicated a high instrument sensitivity.

One of the papers which evinced audience interest was entitled "Mechanical properties of cellular polyurethanes used in the footwear industry" by R. E. Whittaker. A good discussion followed the paper, ranging through lifetimes of ladies' shoes, service conditions and the properties of materials. The paper showed that the footwear industry has expertise in rheological phenomena and is putting effort into evolving a suitable synthetic material for a difficult and complicated application.

Finally, stress relaxation was considered by P. M. Haughton and D. B. Sellen in, "Stress relaxation in regenerated cellulose at low temperatures". The experimental work comprised tensile tests on single fibres of regenerated (viscose) cellulose of about 100 microns diameter. Small strains were imposed instantaneously and the stress relaxation measured during a 0.03–1000 second interval.

The temperature range covered was $+20^{\circ}\text{C}$ to -185°C . Satisfactory interpretation of the results was not obtained either with the Eyring theory or a hydrogen bond theory.

On this somewhat indefinite note, a most successful and enjoyable Conference ended some fifteen papers and two and a half days after it commenced. It seems certain that many of the participants, including those from four or five overseas countries, would welcome the opportunity to attend a similar conference in the future and wish to acknowledge the fruitful work of Dr. K. M. Beazley and Dr. M. F. Culpin in organizing it.

J. GODFREY,
J. HARRIS,
School of Chemical Engineering,
The University,
Bradford 7, Yks.

COMPUTER PROGRAM CATALOGUE

During several recent volumes of this Bulletin a number of computer program abstracts have been published. As a reminder to members, a current list of information about these abstracts is appended.

If you have a reliable computer programme of use in the field of rheology and are willing to make it available to others, then one way of making this known is to publish an abstract in the Bulletin. The editor would be pleased to supply an abstract form on request.

Computer Program Abstract

<i>Abstract No. and Reference (BSR Bulletin)</i>	<i>Abstract</i>	<i>Author</i>
1 1969, No. 3, Vol. 12, p. 15	Analysis of viscoelastic results obtained from the Rheovibron model DDV-II viscoelastometer on elastomers and textiles.	P. R. Willett (Australia)
2 1969, No. 3, Vol. 12, p. 16 and 17	The program predicts the phase lag and amplitude ratio of a cone and plate system. Viscoelastic fluids used are Oldroyd 2 constant and Maxwell models and program is ideally suited for Weissenberg rheogoniometry.	M. P. Brocklebank
3 1969, No. 3, Vol. 12, p. 16 and 17	Calculate Reynolds number, friction factor, velocity profile based on Bowen formula, wall shear stress, experimental friction—factor and generalised Reynolds number. Inputs required: flow rate, pressure drop, tube diameter, Bowen constants, power-law constants and fluid density.	A. K. M. A. Quader
4 1969, No. 4, Vol. 12, p. 29	Computes real and imaginary components of viscosity (or rigidity) for each frequency input.	D. Mitchell
5 1970, No. 3, Vol. 13, p. 81	(1) Compute γ (τ) from capillary viscometer data (2) Compute γ (τ) from couette viscometer data.	R. I. Tanner and G. Williams
6 (Analogue) 1971, No. 1, Vol. 14, p. 17	Solution of oscillatory pipe flow for linear elastic fluids. Input Data: Reynolds number and boundary conditions. Output Data: Inphase/quadrature displacement profiles.	J. Harris and A. Jenkins

A NOTE ON EMPIRICISM

In the Foreword to this issue some opening remarks were made on the subject of empiricism. The purpose here is to add further comments which may give the subject some perspective and eliminate some misconceptions.

The Historic Basis

Throughout the history of the theory of knowledge there has been two main streams of thought. One which was much favoured by the Greek philosophers was that our knowledge comes from innate ideas. This led many of them to attempt to discover the nature of the world by speculation alone and on to puzzles in metaphysics, culminating finally in the denial of a physical world, or matter. Such was also the viewpoint of Berkley and this was a direct descendent of the philosophy of Plato whose picture of the universe was that the real, stable and permanent feature is the world of ideas.

The features of sensory experience were considered more in the nature of dreams and as such illusory and even unimportant. Descartes also held a view closely resembling that of Plato and in his view known examples of innate ideas included such things as mathematical objects, like the idea of a circle and more importantly for him, the idea of a Perfect Being, a Deity.

Such theories of knowledge as the speculative type mentioned above are called "rationalistic".

The alternative, empirical, point of view adopted in a clearly recognisable way, is evident in the writings of Sir Francis Bacon and John Locke in the sixteenth and seventeenth centuries. The antecedents however are apparent in the work of Aristotle and Epicurus and still earlier in the work of Democritus, although perhaps their overt intentions were something other than the undeniable of motivations of Bacon and Locke, whose work in philosophy is parallel in time and approach to that of the empirical scientists, Robert Boyle and Robert Hooke.

The work of some contemporary philosophers can also be related to these two distinct threads although the discussions have been cast in different language.

The Philosophic Basis

Doubts about the rationalist theory of knowledge have driven people to formulate ideas which seemed more consistent with ordinary human behaviour. This philosophy begins with sense experience as the *source and basis of what we know*. Furthermore, at every point our ideas should be *capable of being checked directly or indirectly with our sense experience*.

This approach proposes the complete denial of any such entities as innate ideas and it has had its most extensive support in Great

Britain and to a lesser extent in America where it has further developed into pragmatism.

The extent, scope and influence of the philosophy of empiricism is greater than many might suspect. Certainly it embraces a great deal of science.

The Scope of Empiricism

The next step is to fit into the framework of speculative or rationalistic philosophy on the one hand and empirical philosophy on the other, all those publications whose authors agree are about the subject of rheology. It will be seen by using the above definitions as discriminators that almost without exception they fit into an empirical framework, even those which are often considered to be "mathematical". The truth of the matter is that such papers usually start from a foundation of empirical formulae; this fact cannot be altered by subsequent mathematical operations no matter how extensive they may be.

WHY CHOCOLATE NO LONGER OBEYS CASSON'S LAW

While attending the Society's Annual Conference in Exeter, I recalled a paper presented during last year's proceedings in Shrivenham, reporting that the chocolate studied did not obey Casson's Law. It seemed to me that the reason for this was because of a fundamental truth which I am sure fellow rheologists have met in many diverse forms. This is that Mother Nature and many of her offsprings have never been to school, far less university, and do not know about the Laws of Nature that they have to obey. They are plain ignorant and simply do not know how they should behave.

Well, one of Mother Nature's offspring is Chocolate. When she was first born, Newton had already discovered the Law of Viscosity. But she did not know this and so behaved in any old how except with constant viscosity. It happened that her responses to stresses could be correlated by a straight line if the square root of the strain rate is plotted against the square root of the shear stress. Then in 1957, Casson studied the behaviour of suspensions and came upon this Law, which now bears his name. During the intervening years, Casson's Law became well established. It is now textbook stuff and every rheologist knows about it. But I am afraid that Mother Nature's offsprings still do not attend schools and colleges, even in these days of universal education. The new generations of Chocolate still do not know about Newton's Law and, what is more, they are now ignorant even of Casson's Law. This is why Chocolate no longer obeys Casson's Law nowadays.

D.C.H.C.

Any suggestions as to what we should do about it? Ed.

MODERN DEVELOPMENTS IN FLOW MEASUREMENT

A.E.R.E. HARWELL

21-23 September 1971

LIST OF PAPERS

- Industrial Demands for Flow Measurement: C. G. Clayton and G. V. Evans.
- Current Practice in Fluid Flow Measurement: E. A. Spencer.
- Flow Measurement by Weirs and Flumes: P. Ackers.
- Recent Measurement of Flow using Nuclear Magnetic Resonance (N.M.R.) Techniques: J. R. Singer and T. Grover.
- A Vortex Frequency Flowmeter: C. G. Rasmussen.
- Measurement of Volume Flowrate in Disturbed Flow using the Laser Doppler Technique: P. J. Bourke.
- A Development of the Laser Velocimeter: K. A. Blake.
- Flow Measurement in the Presence of Strong Swirl using a Laser Doppler Anemometer: P. S. Bedi and M. T. Thew.
- An Evaluation of Optical Anemometers for Volumetric Flow Measurement of Liquids and Gases: F. Durst, A. Molling and J. H. Whitelaw.
- A Thermo-electric Flowmeter of Rapid Response and Small Sensor Size: A. G. Smith and W. A. K. Said.
- The Development of Thermal Flowmeters for the Measurement of Small Flows of Corrosive and Radioactive Liquors in Chemical Plants: A. L. Mills and C. R. A. Evans.
- Ultrasonic Method of Flow Measurement in Large Conduits and Open Channels: H. Suzuki, H. Nakabori and M. Yamamoto.
- Ultrasonics as a Standard for Volumetric Flow Measurement: S. G. Fisher and P. G. Spink.
- Flow Metering using a Microwave Doppler Meter: J. Harris.
- The Performance of Long Bore Orifices at Low Reynolds Numbers: T. Cousins.
- Non-Newtonian Flow Measurement using Conventional Pressure Difference and other Meters: J. Harris and A. N. Magnall.
- A Pressure Differential Flowmeter with Linear Response: D. Turner.
- Inferential Pipe Flowmeters based on Pressure Loss with Mechanical/Phototronic/Transducer Systems: J. A. Ryland.
- Small Diameter Orifices in Series: S. C. Okafor and R. K. Turton.
- Measurement of Transient Mass Flowmeters of a Gas: N. Mustafa, I. Birchall and W. A. Woods.
- Development of a Pulsed Gas Ionisation Flowmeter; T. J. S. Brain.

- Measurement of Gas Flow by Radiotracer Methods: G. V. Evans, R. Spackman, M. A. J. Aston and C. G. Clayton.
- Flowrate Determination by Neutron Activation Analysis: C. R. Boswell and T. B. Pierce.
- Testing and Comparison of Three Methods of Measuring Flow through Pipes: L. Roche, H. André, S. Gamby and B. Noiret.
- Experience in the Use of the Radioisotope Constant Rate Injection Method in testing the Performance of Hydraulic Machines: C. G. Clayton and G. V. Evans.
- Flow Velocity and Mass Flow Measurement using Natural Turbulence Signals: M. S. Beck, J. Coulthard, P. J. Hewitt and B. Sykes.
- Flow Characteristics of Turbine Flowmeters: V. R. Withers, F. A. Inkley and D. A. Chesters.
- Experimental, Analytical and Tip Clearance Loss Studies in Turbine-type Flowmeters: P. A. K. Tan and S. P. Hutton.
- Modern Development and New Applications of Magnetic Flowmeters: R. Theenhaus.
- Electromagnetic Flowmeters for Liquid Metals: G. Thatcher.
- Errors in the Velocity-Area Method of Measuring Asymmetric Flows in Circular Pipes: L. A. Salami.
- Flow Metering and Future Aims: S. P. Hutton.

VISCOMETERS WITH CURVILINEAR FLOW PATTERNS

Part 1: Concentric Cylinder Viscometer

J. Harris,

University of Bradford, Yorks.

1. Introduction

Viscometers with curvilinear flow patterns are often used to examine the rheological properties of liquids. A simple analysis is carried out using the experimentally measured torque and angular rate of rotation of the inner or outer cylinder, whichever happens to be the driven member, and one pair of cylinders.

These notes outline certain additional features which are rarely, if ever, considered in using rotational viscometers. They point to effects which may be present and which may if not accounted for, reduce the validity of calculated data.

Part 1 treats the concentric cylinder viscometer. Parts II and III to be published in following issues of the Bulletin will treat the parallel plate and cone plate geometries. Section 2 gives some physical reasoning why such considerations may be important.

2. Radial Migration of Particles

Some years ago it was noted by the present author whilst trying to obtain rheological data on whole blood, that during high rotational speed tests on the Weissenberg rheogoniometer the red cells appeared to "centrifuge" radially outwards. This effect should not be unexpected, but of course it pushes the red cells into the region where most of the torque may be generated, i.e. the viscosity is increased where the torque contribution due to shearing the fluid may be highest.

A simple type of investigation can be made if it is considered that a two component material, such as a slurry, has a circular flow pattern of some sort imposed on it. If the radial migration velocity of the particle is observed to be u at a radius r where the angular rate of rotation is w and u is much smaller than rw , the analysis can take the following lines.

The centripetal force is given by equation (1). Assuming a particle Reynolds number less than 2, then Stoke's law (2) can be applied with reasonable accuracy.

Equating (1) and (2) and rearranging produces the relative particle velocity v in (3). Note that v is not exactly the observed particle velocity u because particles migrating radially outwards will displace a less dense fluid radially inwards. The relation between the two is given in (4).

The inwardly directed fluid velocity is given by (5) which is obtained by continuity considerations. Actually, if there are some

smaller sized particles of the same material present whose radial migration velocity is less than u' some particles will be swept inwards. These particles will be of diameter given by (6). If several particle sizes are present then bands of particles can be expected to occur which will be an intermediate and temporary pattern. Ultimately, all particles of greater density than the surrounding fluid will migrate towards the perimeter of the field.

If we assume that initially the radial gradient of the concentration is small then continuity considerations lead to equation (7) in which use has been made of (3) and (4).

Integrating (7) and assuming a uniform volume concentration c_0 everywhere on time $t = 0$, the distribution (8) results in which the angular velocity w is a function of radius. The specification of this function completes the description of the distribution of the concentration c , at least for small t .

3. Concentric Cylinders—Inner Cylinder Rotating

The actual velocity profile distribution and hence that of w in (3) can be found in this case by starting from the shear rate distribution (9). Integrating and applying the condition that $wr = 0$ on $r = R_2$, gives the distribution (10) or (11). Note that both (10) and (11) are only applicable if the radial viscosity distribution is constant, which it cannot be exactly if there are significant concentration gradients due to particle migration.

Therefore with the proviso that only small departures of the current concentration c from the initial uniform concentration c_0 are allowed: Combining (3), (4) and (11) yields (12).

As an example. Take a 10% v/v concentration of particles of density $2.5 \times 10^3 \text{ kg/m}^3$ in a liquid of viscosity 10^{-3} Ns/m^2 and suppose the particles are 10 microns diameter. The inner cylinder is of 2 cm. radius and is rotated at 486 r.p.m. The outer cylinder is of 2.1 cm radius. What will the radial migration velocity at the inner wall be? (These conditions are obtainable in the Haake Rotovisco viscometer.) How long will it take to establish an annulus of clear fluid of width equal to ten particle diameters?

Substituting the values in formula (12) shows that the particle migration velocity is $6.5 \times 10^{-4} \text{ m/s}$. The time taken to produce a clear annulus of fluid equal to ten particle diameters is only 0.154 seconds. This is well below the response time of the instrument in these examples.

4. Effective Slip at the Boundary

We have just seen that a zone of diminished concentration may occur at the solid boundary in concentric cylinder viscometry. This

can produce an effective slip velocity which may, in the same approximation involved as (11), be detected by a plot of data for different gap widths ($R_2 - R_1$) as shown in figure 1.

In a manner which is analogous to the well-known method for finding slip at the wall of a pipe, the effective slip velocity is given by (13). The experimental data in figure 1 is intersected by a line A-B to find U_s in (13). Ideally, the width of the interval on the inner and outer cylinder shear stress curves should be the same for both gap widths.

5. The Shear Rate at the Wall

If concentration gradients exist in the concentric cylinder type of viscometer, and the indications in this work are that this is a definite possibility, then the velocity profile will depart from the pattern obtainable with a uniform concentration.

Starting from (14) and (15) and integrating produces (16). This may be differentiated with respect to the upper or lower limit of the integral to find the shear rate at that point. For example differentiating with respect to the lower limit produces (17). Practically, this differentiation process is executed on experimental data as shown in figure 2.

6. Normal Stress Measurement at the Wall

Now that the factors such as wall slip and wall shear rate have been treated it is natural to complete the investigation by considering the measurement of normal stress at the wall.

Starting from the equilibrium equation (18) and using (15) to change the independent variable; equation (19) can be combined with (20) and integrated to produce (21). Again differentiating with respect to the upper limit produces (22) which represent the normal stress difference at the outer cylinder wall. Naturally, a corresponding differentiation with respect to the lower limit is possible in (21) to produce the normal stress difference at the inner wall.

Figure 3 shows how the differentiation process is carried out graphically by obtaining experimental data for different gap widths.

7. Rotating Outer Cylinder

A treatment along the lines given is of course possible for the case of a fixed inner and rotating outer cylinder. The velocity field in this case is given by (23), (approximately).

In this case the radial migration of solid particles of density greater than the surrounding fluid is zero at the inner cylinder. But in an emulsion for example with a light disperse phase a radially *inwards* migration of particles could be expected.

8. Conclusion

In the normal time scale of viscometric measurements on commercially available equipment, significant radial migration of particles may occur in two component (or two phase) materials. The treatment of data, allowing for these effects, is more complicated than the simple treatments normally employed and calls for data from a number of cylinders with different diameter combinations. The treatment may also be employed where there are non-Newtonian effects but no significant radial migration of particles.

The formulae in these notes were constructed in the main about seven years ago.

Parts II and III will follow in other editions of the Bulletin.

VISCOMETERS WITH CURVILINEAR FLOW PATTERNS

Part I: Concentric Cylinder Viscometer

Formulae and Figures

$$F = \frac{\pi}{6} p_s d^3 w^2 r \quad (1)$$

where p_s is the particle density.

d is the particle diameter.

r is the radius of particle path line about the centre of rotation.

$$F = 3\pi\mu v d p \quad (2)$$

where μ , p are the *liquid* viscosity and density respectively.

v is the velocity of the fluid relative to the particle.

$$v = \frac{p_s d^2}{18\mu} w^2 r \quad (3)$$

$$v = \frac{u}{1-c} \quad (4)$$

where c is the solids concentration (v/v) . $c = c(r, t)$

$$u' = - \frac{cu}{1-c} \quad (5)$$

where u' is the fluid velocity

$$d' < dc^{1/2} \quad (6)$$

$$\left. \begin{aligned} \frac{\partial c}{\partial t} + \frac{c}{r} \cdot \frac{\partial}{\partial r} (r \cdot u) &= 0 \\ \frac{\partial c}{\partial t} + \frac{c(1-c)}{r} \frac{p_s d^2}{18\mu} \frac{\partial}{\partial r} (w^2 r) &= 0 \end{aligned} \right\} \quad (7)$$

$$c = \left[\frac{\left(\frac{c_o}{1-c_o} \right) \exp - \frac{Kt}{r} \frac{\partial}{\partial r} (w^2 r)}{1 + \left(\frac{c_o}{1-c_o} \right) \exp - \frac{Kt}{r} \frac{\partial}{\partial r} (w^2 r)} \right] \quad (8)$$

$$\left(K = \frac{p_s d^2}{18\mu} \right)$$

$$\dot{\gamma} = \frac{T}{2\pi\mu r^2} = r \frac{dw}{dr} \quad (9)$$

where $\dot{\gamma}$ is the shear rate.

T is the torque/unit cylinder depth.

μ is the viscosity.

$$wr = \frac{T}{4\pi\mu} \left(\frac{r}{R_2^2} - \frac{1}{r} \right) \quad (10)$$

$$w = \Omega \left(\frac{R_2 - r}{R_2 - R_1} \right) \quad (\text{Approximately}) \quad (11)$$

$$u = (1-c) \frac{p_s d^2}{18\mu} \left[\frac{\Omega (R_2 - r)}{(R_2 - R_1)} \right]^2 r \quad (12)$$

where Ω is the angular speed of the inner cylinder.

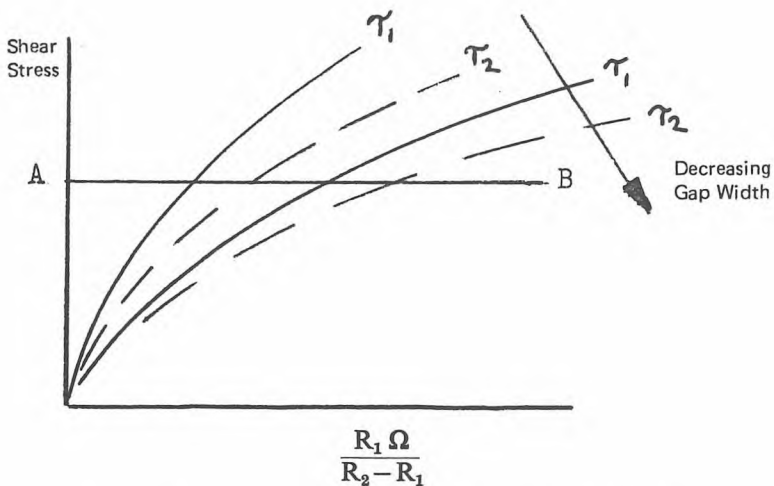


FIG. 1. CONCENTRIC CYLINDER DATA WITH WALL SLIP

$$u_s = \frac{\partial \left(\frac{R_1 \Omega}{R_2 - R_1} \right)}{\partial \left(\frac{1}{R_2 - R_1} \right)} \quad \text{(At constant wall shear stress)} \quad (13)$$

$$\dot{\gamma} = f(\tau) \quad (14)$$

torque

$$T = 2\pi r^2 \tau \quad (15)$$

$$\Omega = \frac{1}{2} \int_{\tau_2}^{\tau_1} \frac{1}{\tau} f(\tau) d\tau \quad (16)$$

$$f(\tau_2) = -2\Omega \frac{d \ln \Omega}{d \ln \tau_2} \quad (17)$$

or,

$$f(\tau_1) = 2\Omega \frac{d \ln \Omega}{d \ln \tau_1} \quad (17a)$$

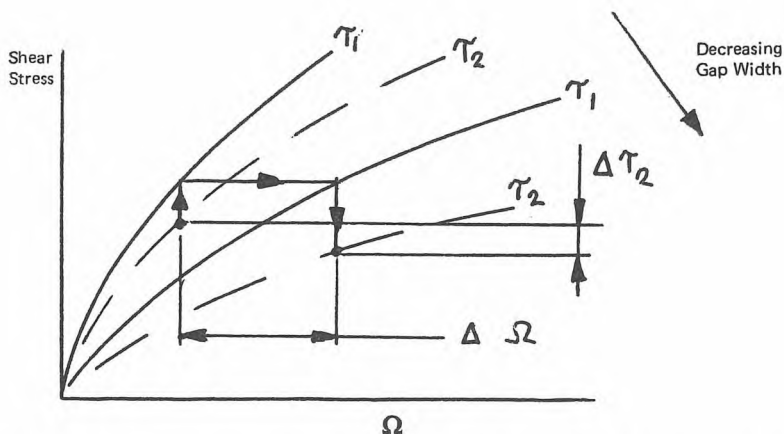


FIG. 2. DIFFERENTIATION OF EXPERIMENTAL DATA FOR EQUATION (17)

$$\frac{\partial \tau_{rr}}{\partial r} + \frac{(\tau_{rr} - \tau_{\theta\theta})}{r} = 0 \quad (18)$$

$$-2 \frac{\partial \tau_{rr}}{\partial \tau} + \frac{(\tau_{rr} - \tau_{\theta\theta})}{\tau} = 0 \quad (19)$$

$$\tau_{rr} - \tau_{\theta\theta} = g(\tau) \quad (20)$$

$$\tau_{RR2} - \tau_{RR1} = \frac{1}{2} \int_{\tau_1}^{\tau_2} \frac{1}{\tau} g(\tau) d\tau \quad (21)$$

$$g(\tau_2) = 2\tau_2 \frac{d}{d\tau_2} (\tau_{RR2} - \tau_{RR1}) \quad (22)$$

$$\text{also } g(\tau_1) = -2\tau_1 \frac{d}{d\tau_1} (\tau_{RR2} - \tau_{RR1}) \quad (22a)$$

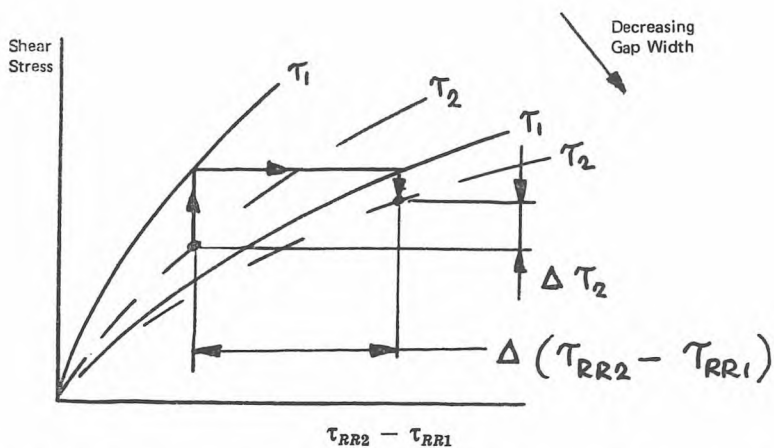


FIG. 3. DIFFERENTIATION OF EXPERIMENTAL DATA FOR EQUATION (22)

$$w r = R_2 \Omega \left(\frac{r - R_1}{R_2 - R_1} \right) \quad (23)$$

NOTES ON FUTURE MEETINGS

Plastics Institute Meetings

Full day and in London unless otherwise indicated

1st Dec. Meeting (p.m.): The injection moulding of thermo-setting polyesters, *Solihull*.

1972

2nd Feb. Meeting (p.m.): Towards cheaper mould making, *Solihull*.

16th Feb. Symposium (p.m.): Polyurethanes and P.V.C. as coating materials, *Manchester*.

22nd/23rd Feb. Conference: Development in films for packaging.

1st Mar. Symposium (p.m.): Outstanding national successes.

8th Mar. Seminar: Capital investment decisions, *Sully*.

15th/16th Mar. Conference: Filament winding II.

22nd Mar. Symposium: Fire insurance and the use of plastics in buildings, in contents and as packing materials.

11th/13th April Seminar: Polymers in the transportation industry, *Nottingham*.

13th April Symposium: Moulding expanded materials, *Bath*.

10th May Assessment of plastics for use in building, *Building Research Station*.

May/June Conference: Degradable plastics.

27th Sept. Symposium: Reinforced plastics—recent advances in the marine field, *Southampton*.

Sept./Oct. Conference: Plastics for paper replacement.

5th/6th Oct. Conference: Testing of polymers for service, *Buxton*.

29th/30th Nov. 2nd Plastics Institute National Technical Conference (P.I.N.T.E.C.).

Provisional Programme of Main Events 1973-74

1973

8th/10th Jan. 5th Cranfield conference: Designing to avoid failure.

20th/21st Feb. Conference: Plastics in bearings, *Solihull*.

26th/29th Mar. 2nd Churchill conference: Yield, deformation and fracture of polymers, *Cambridge*.

March Conference: Rotational/structural foam moulding, *Manchester*.

April Conference: Reinforced plastics in aerospace applications.

7th/11th May	S.P.E./P.I. joint conference, <i>Montreal</i> .
18th/20th June	Conference: Plastics industries in the developing world.
Aug./Sept.	I.U.P.A.C. International symposium on macromolecules, <i>Aberdeen</i> .
September	Conference: Advances in plastics processing machinery, <i>Solihull</i> .
November	Conference: Plastics in furniture II.
1974	
February	Conference: Carbon fibres II.

Second International Conference
Yield, Deformation and Fracture of Polymers
Churchill College, University of Cambridge
26th–28th March 1973

Following the successful conference on the physical and structural basis of yield deformation and fracture of polymers held at Cambridge in 1970 a second conference on the same subject is being organized. It will be held at Churchill College, Cambridge, from 26th to 29th March 1973 and is being organized by a committee representing the following British societies:

Plastics Institute (providing the secretariat).

British Society of Rheology.

Institute of Physics—Materials and Testing Group.
—Polymer Physics Group.

Institution of Metallurgists.

Institution of the Rubber Industry.

Materials Science Club.

Society of Chemical Industry—Plastics and Polymer Group.

The programme will consist of about 24 papers on original research arranged in six sessions allowing 20–25 minutes for presentation and 10–15 minutes for discussion of each paper. In addition to the papers each session will be opened by a brief introductory review given by the Chairman for that session.

Those interested in submitting papers for presentation at the conference are asked to write to the Secretary, the Plastics Institute.

Joint Conference 1972

Rheology of Lubricants

Arrangements have been made for a Joint Institute of Petroleum/Institute of Mechanical Engineers/British Society of Rheology meeting 6th-7th July 1972. Accommodation has been arranged at the Byron Hall, Shakespeare Street, Nottingham. The Hall comprises a lecture theatre/dining and bedroom/sports and games complex, all of which will be available to participants. There will be a Conference Dinner on the first evening.

It is planned to make preprints available prior to the Conference and to publish the proceedings in the autumn of 1972.

The main headings to be covered are:

1. The Rheology of Petroleum-based Lubricants.
2. The Rheology of Synthetic Lubricants.
3. The Rheology of Greases.
4. Biological Lubricants.
5. New Concepts in Theoretical and Experimental Rheology.
6. Non-conventional Lubricants.

Papers are invited for the above meeting and abstracts of about 200 words may be sent to:

Mr. C. H. Maynard,
Institute of Petroleum,
61 New Cavendish Street,
London W1M 8AR.

Sixth International Congress on Rheology

Lyon, France

September 4th-8th, 1972

Subjects

Papers on the following aspects of rheology will be presented during the congress:

- i. Theory.
- ii. Measuring techniques.
- iii. Test methods.
- iv. Fractures.
- v. Rheologic properties of materials:
 - (a) vapours and gases
 - (b) liquids
 - (c) polymers in the solid state: fibres, films, elastomers and plastics

- (d) polymers in solution and melts
 - (e) emulsions, suspensions and powders
 - (f) metals and other crystalline materials
 - (g) foods
 - (h) oils and fats
 - (i) cosmetics and drugs
 - (j) paints and printing inks
 - (m) adhesives and lubricants
 - (n) wood and other natural products
 - (o) glass and ceramics
 - (p) concrete and mortars
 - (r) soils and rocks
 - (s) miscellaneous
- vi. Rheo-optic.
 - vii. Bio-rheology.
 - viii. Miscellaneous.

Inscriptions and Papers

All who wish to have more complete details of the programme, the papers and participation, are invited to write to the congress secretary before November 1st, 1971.

Persons who wish to present a paper should indicate the category into which it falls principally, according to the subject list on page 6. The presentation of the paper together with discussion time should be about 20 minutes. The title and an abstract of no more than 300 words should be addressed to the organising secretary before March 1st, 1972.

Dr. C. SMADJA,
Boîte Postale n° 1,
69 Lyon-Mouche,
France.

Chemical Society Summer School in Rheology

9-13 April, 1973—School of Pharmacy, London

Organiser: Professor E. Shotton, School of Pharmacy, London

A Summer School is being planned which will be of interest to chemists in a wide variety of industries who would like to learn something of the rheology of materials and of experimental methods. The Course will be of value to chemists in the pharmaceutical, cosmetics, food, metals, ceramics, paints and printing ink industries, and will be suitable for those of graduate status.

At the beginning of the week basic principles and underlying theory will be dealt with, in a format of morning lectures and afternoon problem-solving tutorials and demonstrations. Later in the week the School will deal with applications of rheological principles to specific systems, probably under the following headings:

Dispersed Systems—emulsions, suspensions and pastes.

Plastics and Rubber—higher elastics and solids.

Solids—both crystalline and amorphous.

Further details will be available in due course, and these may be obtained by writing to Dr. M. D. Robinson, Education Officer, The Chemical Society, Burlington House, Piccadilly, London, W1V 0BN. Professor Shotton will be pleased to answer technical enquiries concerning the School.

Symflo 72

Symposium on Flow—Its Measurement and Control in Science and the Chemical Industry

SYMFO 72 will be held in the Renold Building of UMIST on 19th and 20th April, 1972, with associated works visits held on 21st April.

Emphasis will be placed on the following themes:

1. Flow characteristics.
2. Flow measurement equipment.
3. Flow measurement and control techniques.
4. Flow in the chemical industry.
5. Biological fluid flows.

Further details from: R. Maley, Esq.,
11 Glencoe Drive,
Sale,
Cheshire.

DIARY

1972

11–13 April. Conference—Polymers in the Transportation Industry, Joint I.Prod.E./P.I./I.E.D./S.E.E. Meeting.

15–18 May. Conference—International Rubber Conference, Brighton I.R.I.

22–24 May. Conference—Plastics in Mechanical Engineering, I.Mech.E./P.I.

6–7 July. Conference—Rheology of Lubricants. Joint Inst. Pet./I.Mech.E./B.S.R. at Trent Polytechnic, Nottingham.

4–8 September. Congress—6th International Congress on Rheology, Lyon, France.

Consult "Notes on Future Meetings" for further information.

WE WOULD LIKE TO HEAR FROM YOU

B.S.R. members are reminded that the Editor of the *Bulletin* is always interested in receiving informative articles, comments, news and other material which would help to make the *Bulletin* one of the more welcome sights in the flood of reading matter to which most of us are accustomed and resigned.

Suggestions of possible improvements in the *Bulletin* would also be welcome. So if you have a thought and a minute to put pen to paper why not let us hear about it?