

THE BRITISH SOCIETY OF RHEOLOGY

BULLETIN



1985, VOL, 28 No. 3

CONTENTS

Officers and Members of Council	i
Editorial	ii
Engineering Applications	25
Membership News	32
The Leaking Bucket	33
News of Meetings	33
Advertisements	

Hon. Editor
Dr H A Barnes,
Unilever Research
Port Sunlight Laboratory,
Bebington, Wirral,
Merseyside, L63 3JW

ISSN-0045-3145

OFFICERS AND MEMBERS OF COUNCIL



PRESIDENT: PROF. I.M. WARD, Dept. of Physics, University of Leeds, Leeds, LS2 9JT.

SECRETARY: DR J.J. BENBOW, Dept. of Chemical Engineering, University of Birmingham, P.O. Box 363, Birmingham, B15 2TT. (Telephone: 021-472-1301, ext. 2789).

TREASURER: MR T.A. STRIVENS, Physics Section, Research and Development Dept., ICI (Paints Division) Ltd., Wexham Road, Slough, Berkshire, SL2 5DS.

MEMBERSHIP SECRETARY: DR P.C. ANDERSON, B.P. Research Centre, Chertsey Road, Sunbury-on-Thames, Middlesex, TW16 7LN.

ABSTRACTS EDITOR: DR D.R. OLIVER, Dept. of Chemical Engineering, University of Birmingham, P.O. Box 363, Birmingham, B15 2TT.

BULLETIN EDITOR: DR H.A. BARNES, Unilever Research, Port Sunlight Laboratory, Bebington, Wirral, Merseyside, L63 3JW.

ORDINARY MEMBERS:

DR S.T.E. ALDEHOUSE, B.P. Chemical, Research and Development Dept., Sully, South Glamorgan, CF6 2YU.

DR F.S. BAKER, PERME (W.A.), M.o.D., Waltham Abbey, Essex.

DR D.C-H. CHENG, Warren Spring Laboratory, Stevenage, Hertfordshire, SG1 2BX.

DR A. EVANS, Dept. of Surgery, Royal Victoria Infirmary, Newcastle-upon-Tyne, NE1 4LP.

DR C.J.S. PETRIE, Dept. of Engineering Mathematics, University of Newcastle-upon-Tyne, Newcastle-upon-Tyne, NE1 7RU.

MR H. SCHIMANSKI, Contraves Industrial Products, Times House, Station Approach, Ruislip, Middlesex, HA4 8LH.

EDITORIAL

The "leaking bucket" runs on! Prof. Prof. Rigbi, who posed the original question to Jack Astin, comments on Prof. Astarita's simple solution.

Prof. Mike Edwards has kindly allowed us to reproduce his lecture on "Engineering Aspects of Rheology in the Process Industries", given earlier in the year at the joint R.S.C./B.S.R. one day meeting.

The latest LIST OF MEMBERS has the useful facility that the telephone numbers of many members are listed. Peter Anderson is to be congratulated for his fine effort, especially as he typed all the entries himself!

New Meetings advertised in this issue remind us of areas of rheology that are often neglected - surface and solids - but which are nevertheless very important.

Have a good read!

A handwritten signature in cursive script, reading "H A Barnes".

H A BARNES

RHEOLOGY IN THE PROCESS INDUSTRIES

"ENGINEERING APPLICATIONS"

by

M. F. Edwards,
Schools of Chemical Engineering,
University of Bradford,
BRADFORD,
West Yorkshire,
BD7 1DP

1. Introduction

The use of rheological data for the design and analysis of a range of engineering applications is considered in this paper. Pipeflow, mixing, heat transfer and some specialised processing methods for materials of complex rheology are covered.

In this brief paper it is not possible to mention every published study. However, an attempt is made to highlight the key issues in order that the reader may appreciate what can be done in a routine way, what are difficult problems and which topics still remain impossible.

It will be assumed throughout that reliable rheological data are available for the materials under consideration. However, it must be realised that the acquisition of such data is often not straightforward. Furthermore, it is essential to ensure that the rheological data cover the same shear rate (or extension rate) range as that in the equipment to be designed or analysed. For heat transfer studies the rheological data must also be obtained over the appropriate range of temperatures.

2. Isothermal Pipe Flow

- 2(i) For straight pipe sections with laminar flow neglecting entrance and exit effects standard procedures exist for the calculation of the velocity profile and the flow rate/pressure drop relationship. Such calculations are based on the solution of the equation of motion coupled with an appropriate model of rheological behaviour^(1,2). In this way velocity profiles and pressure drop data can readily be evaluated for model fluids described by the power law, Bingham plastic, Ellis model etc. In addition it is relatively straightforward to use rheological data in numerical form in these calculations.

For engineers it is important to appreciate that pseudoplasticity leads to a closer approach to plug flow than the familiar Newtonian parabolic velocity profile laminar conditions. Thus the residence time distribution is narrower for shear thinning materials and this favours uniform processing of all the fluid in the pipe. Dilatancy on the other hand widens the residence time distribution. For materials with a "yield stress" there will be a central plug of material whose size depends upon the relative magnitude of the applied pressure gradient (and hence wall shear stress) and the yield stress of the fluid^(1,2).

- 2(ii) For the case of turbulent flow of non-Newtonian materials the position is not clear and it is fortunate that many non-Newtonian liquids will be processed under laminar conditions due to their high viscosity. However, it is possible with some materials to achieve turbulent flow conditions economically in pipeline systems. In some such systems the phenomenon of drag-reduction appears and this is by no means completely understood^(3,4).

For many cases of turbulent flow in large scale engineering systems it is preferable to scale up from small scale turbulent flow tests^(5,6) rather than to proceed from laminar rheological data alone. However, some procedures are available based on this latter approach⁽⁷⁾.

In the case of slurry transport, care must be taken to account for any settling which may occur in the pipeline⁽⁸⁾.

- 2(iii) Pipe fittings - In many pump/pipeline systems the major contribution of the head loss does not come from the straight pipe sections but from the fittings. These include entrance region, exits, expansions, contractions, bends, valves, orifice plates, etc.

The calculation of head losses with non-Newtonian fluids at low Reynolds number is not well documented and further work is required in this area. Some recent data based on the experimental evaluation of loss coefficients for a variety of fittings has been published⁽⁹⁾ and this work is concerned with inelastic fluids. If however, the material is significantly elastic then the purely viscous analysis may be inadequate. This will, of course, depend upon the characteristic time scale of the fluid and the process. In such situations the recent numerical approaches of Crochet⁽¹⁰⁾ will be of use.

3. Isothermal Flow in Channels of Complex Geometry

In many processes involving polymer melts, foodstuffs, pharmaceutical products etc. the material flows through equipment with complex geometry channels. A relatively simple geometry would be that in dies for shaping extruded polymer melts. Here some analytical solutions based on the lubrication approximation may be possible to predict flowrate/pressure drop relationships^(11,12). However, this approach will only be valid for channels whose cross section change gradually.

For most problems a numerical solution will be necessary based on finite difference or finite element packages^(10,13,14). In all such numerical packages the accuracy of the resulting solution will depend critically on rheological data which is fed into them as input data.

4. Heat Transfer in Circular Tubes

- 4(i) In the case of heat transfer to non-Newtonian fluids in laminar flow, theoretical studies are based on solutions of the equations of motion and energy⁽¹⁵⁾. In such situations it is the influence of non-Newtonian rheology upon the velocity profile (see section 2(ii)) that is relevant since the velocity profile appears in the energy equation thus affecting the temperature profile and the resultant heat transfer coefficient.

Several solutions of the combined equations of motion and energy are possible depending upon the assumptions made for the

inlet velocity profile

inlet temperature profile

wall heating or cooling condition

temperature dependence of the rheology viscous dissipation effects

The most complete solutions require a numerical technique and computer evaluation based usually upon finite difference methods although finite element solutions have been introduced more recently.

Problems of viscous dissipation are most commonly met with polymer melts where very high pressures are required to drive the material through dies. However, for liquids of much lower viscosity it is often possible to ignore viscous dissipation.

Finally, it should be remembered that either heating or cooling in a tube will markedly influence the pressure drop. However, this non-isothermal pressure drop should be relatively easy to extract from the numerical solutions of the equations of motion and energy.

In the literature there are hundreds of different solutions to the various laminar heat transfer situations in tubes. The review of Porter⁽¹⁶⁾ provides a reasonable introduction although there are many more relevant computed solutions.

For many engineering situations it is reasonable to assume a fully developed velocity profile whereas solutions based upon fully developed temperature profiles will generally give gross underestimates of the rates of heat transfer⁽¹⁶⁾. Furthermore, studies clearly indicate that it is important to make allowance for the temperature dependence of viscous properties⁽¹⁷⁾ since this effect can often outweigh the variation of apparent viscosity with shear rate. Usually shear thinning behaviour and heating from the wall to the fluid will result in heat transfer rates higher than those for the Newtonian liquid with a temperature independent viscosity. On the other hand dilatancy and cooling lead to reduced rate of heat transfer. In all these cases the effect can be inferred by the influence upon the velocity profile.

Several solutions (e.g. 18) include the effect of viscous heating but this will only be significant for materials of very high apparent viscosity where the driving pressure drop is large. Typically a 200

bar pressure drop will produce a mean temperature rise of 5°C. However, it must be remembered that the local rise may greatly exceed 5°C and this could influence thermally unstable materials.

- (4ii) For turbulent flow in pipes the approach is often based upon the analogy between momentum and heat transfer. However, this method has only met with partial success⁽²⁾ and it can be argued that with suspensions the contribution of the solid to momentum transfer will be quite different from that to heat transfer. Alternative approaches based on the use of eddy viscosity expressions for turbulent non-Newtonian flow including drag reduction have recently been put forward⁽¹⁹⁾ and extended also to mass transfer⁽²⁰⁾.
- 4(iii) For plate heat exchangers it is possible to use modified versions of the conventional pipe flow equations using the hydraulic radius approach. Thus it is possible to analyse heat transfer in the complex corrugated channels of a plate heat exchanger using a relatively simple 1-dimensional approach⁽²¹⁾. This technique is capable of correlating pressure drop and heat transfer data for a variety of heat exchanger corrugations for a range of non-Newtonian liquids. Here it must be remembered that in such complex channels with repeated changes in cross section fluid elasticity could become an important factor although analyses based on purely viscous behaviour are usually found to be adequate.
- 4(iv) In-line mixers - such static mixing elements can be used in the laminar tube flow of viscous liquids. Here the straight, axial laminar streamlines are deflected giving significant radial velocities and hence improved heat transfer. This benefit in heat transfer is paid for at the expense of increased pressure drop and hence pumping cost. A review of heat transfer in in-line static mixers has been published recently⁽²²⁾.
- 4(v) Heat transfer in mechanically agitated vessels - this will be considered in the following section on Mixing.

5. Mixing

If highly viscous liquids are to be processed under laminar flow conditions then turbulent mixing will be absent and molecular diffusion will be slow and thus only significant once the interfacial contact area between the components to be mixed becomes very large: that is, when significant mixing has already taken place. In such laminar flow situations mixing can be achieved in:

- a) laminar shearing operations;
- b) in extensional flow
- c) by "cutting and folding" mechanisms.

Recently the mixing in shear and extension has been compared⁽²³⁾ and the cutting and folding is a distributive mixing process such as that which occurs in in-line static mixers⁽²²⁾.

In most commercial mixing equipment a combination of the above mechanisms occurs and it is important that these should be well understood if equipment is to be correctly selected and optimised.

- 5(i) In the case of mechanically agitated vessels much attention has been focussed upon the prediction of power requirement using the "average shear rate" concept⁽²⁴⁾. This is taken as being directly proportional to the impeller speed and the constant of proportionality has been derived for many common impellers⁽²⁵⁾. It is then a simple procedure to calculate the average shear rate and from the flow curve for the material, read off the "average apparent viscosity". It is then possible to calculate the power requirement using the Newtonian procedure^(2,25) by replacing the Newtonian viscosity with the "average apparent viscosity". This approach is forced to work in the laminar region. In the fully turbulent region the viscosity does not significantly influence power input. However, in the transitional region this average shear rate may over-estimate the actual power requirement.

For many engineering purposes the method outlined above is satisfactory. However, care must be taken if the fluid exhibits strong viscoelasticity or if the material has a yield stress or is so shear thinning that the entire vessel contents are not in motion⁽²⁶⁾.

For heat transfer in mixing vessels it is possible to extend the approach for Newtonian liquids using the average shear rate concept^(27,28).

- 5(ii) For internal mixers the mixing occurs in the clearance region between the rotor and the casing and this can be analysed using laminar shearing or extensional flow considerations⁽²⁵⁾.
- 5(iii) In single screw plasticating extruders it is usual to analyse the mixing process which occurs in the melt filled metering section⁽²⁹⁾. However, recent work⁽³⁰⁾ has shown that much mixing also occurs during melting. Furthermore, the laminar shearing theory which is applied to the metering section appears to overestimate grossly the extent of mixing.

6. Interaction Between Processing and Structure

Many non-Newtonian materials are encountered in the food, pharmaceutical and plastics industry where the final structure of the product (e.g. its texture, crystallinity, rheology) is critically influenced by the earlier processing. Typical examples include:

- (i) the cooking extrusion of foodstuffs where the extruder operating conditions can affect both the texture and the nutritional content of the product;
- (ii) the product from bioreactors will depend critically upon the shearing, mass transfer and temperature conditions in the reactor;
- (iii) in cooling thermoplastic extrudates the cooling conditions can influence the microstructure of the article and the residual stresses which are frozen into it.

In such cases as those listed above, it is essential that the interaction between processing and product quality is used to best advantage. It will usually be necessary to involve scientists (e.g. food, polymer scientists, pharmacists) with rheologists and process engineers in an interdisciplinary effort.

References

1. Wilkinson, W. L., "Non-Newtonian Fluids", Pergamon, London, 1960.
2. Skelland, A.H.P., "Non-Newtonian Flow and Heat Transfer", Wiley, 1967.
3. Virk, P. S., A.I.Ch.E.Jnl., 21, 265 (1975).
4. Edwards, M. F. and Smith, R., Jnl. Non-Newt. Fluid Mech. 7, 153 (1980).
5. Edwards, M. F. and Smith, R., Jnl. Non-Newt. Fluid Mech. 7, 77 (1980).
6. Harris, J., Rheol. Acta 7, 228 (1968).
7. Cheng, D. C-H. and Whittaker, W., "Proc. 2nd Conf. on Hydraulic Transport in Pipes", Paper C3, (1972).
8. Thomas, D. G., A.I.Ch.E.Jnl. 7, 423 (1961).
9. Edwards, M. F., Jadallah, M.S.M. and Smith, R., Chem. Eng. Res. Des. (I.Chem.E.) 63, 43 (1985).
10. Crochet, M., paper at present conference.
11. Pearson, J.R.A., "Mechanical Principles of Polymer Melt Processing", Pergamon, 1966.
12. Tadmor, Z. and Gogos, C. G., "Principles of Polymer Processing", Wiley, 1979.
13. Various papers by Spalding, D. B. and co-workers, Imperial College, London.
14. Various papers by Pittman and co-workers, University College, Swansea.
15. Bird, R. D., Stewart, W. E. and Lightfoot, E. N., "Transport Phenomena", Wiley, 1966.
16. Porter, J., Trans. Inst. Chem. Engrs. 49, 1 (1971).
17. Christiansen, E. B., Jensen, G. E. and Tao, F. S., A.I.Ch.E.Jnl. 12, 1196 (1966).
18. Forrest, G. and Wilkinson, W. L., Trans.I.Chem.E., 51, 331 (1973).
19. Smith, R. and Edwards, M. F., Int. Jnl. Heat & Mass Transfer, 24, 1059, (1981).
20. Smith, R., Edwards, M. F. and Wang, H. Z., Int. Jnl. Heat & Mass Transfer, 25, 1869 (1982).
21. Edwards, M. F., Chungal-Vaie, A. A. & Parrott, D. L., The Chemical Engineer 286, May (1974).
22. Edwards, M. F. in "Low Reynolds Number Flow Heat Exchangers", Hemisphere, (1983).
23. Cheng, D. C-H., "Proc. 3rd European Conf. on Mixing", BHRA, Cranfield, 1, 73 (April 1979).
24. Metzner, A. B. and Otto, R. E., A.I.Ch.E.Jnl. 3, 3 (1957).

25. Harnby, N., Edwards, M. F. and Nienow, A. W., "Mixing in the Process Industries", Butterworths 1985 (in press).
26. Nienow, A. W., paper presented at this meeting.
27. Edwards, M. F. and Shamlou, P. A. in "Low Reynolds Number Heat Exchangers", Hemisphere, (1983).
28. Edney, H.G.S. and Edwards, M. F., Trans.I.Chem.E. 54, 160 (1976).
29. Pinto, G. and Tadmor, Z., Polym. Eng. Sci. 10, 279, (1970).
30. Edwards, M. F. and Shales, R. W., paper at MultiStream '85, "I.Chem.E. Symp. Series No. 94".

ANNUAL SUBSCRIPTION REMINDER

The annual membership subscription of £5 for the year 1985/86 falls due for payment on the 1st of October 1985. May I remind all members who have not paid in advance or who do not pay by Banker's standing order to send their payment now to:

The Hon. Membership Secretary
Mr P.C.Anderson
32 Queensway
Feltham
MIDDLESEX
TW13 7NS

It would be very helpful if all those members who do not yet pay by Banker's standing order, could arrange so to do. It would save a great deal of time spent in sending out individual reminders. The order, to pay £5 each year on the 1st of October, should be made payable to the British Society of Rheology Membership Dues account, number 0180985 at Lloyds Bank, 20 North St., Leatherhead, Surrey. (Branch code number 30-94-94). In addition please also notify me at the above address that you have so instructed your bank.

Overseas members, who pay their subscriptions in a currency other than Sterling, should add the equivalent of £1.60 to cover our exchange costs. A single payment may be used to pay for a number of years in advance and/or for any number of members to save exchange expenses.

As an incentive to encourage prompt payment of subscriptions and to help defray the administrative costs of sending out reminders, a proposal will be put to the Annual General Meeting this year as follows: In the event of a member's subscription not having been paid by the 1st of January, three months after it falls due, the amount owing will be increased by £1 to £6.

MEMBERSHIP NEWS

The following applications for Membership were approved at the Council Meeting on 5th July 1985.

Mr Nigel RUDDOCK,
Dept. of Mathematics,
Plymouth Polytechnic,
Plymouth, Devon
PL4 8AA

B.Sc., M.Sc

fetsa BC

Dr Andrew THOMAS,
Dept. of Maths, Stats & Computing,
Plymouth Polytechnic,
Plymouth, Devon
PL4 8AA

BA, MA, Ph.D.

fts FG

Mrs Lindsay Jayne VINEY,
Warren Spring Laboratory,
Gunnels Wood Road,
Stevenage, Herts
SG1 2BX

eta ABCDEFGHIJKLMN

HONORARY MEMBERSHIP

The following members have been elected to Honorary Membership of the Society:

Dr K. Beazley, St. Austell, Cornwall. Ken served on the Society's Council from 1967-1977 and was awarded the Society's Annual Award in 1984.

Mr J. F. Hutton, ex Shell Research Labs, Thornton. John joined the Society in 1954, served on the Council from 1956 to 1966 and from 1970 to 1984, and was the President of the Society in 1982-1984.

Mr P. Langborne, ex National Engineering Laboratories, Glasgow. Paul joined the Society in 1958.

Prof. K. Walters, Dept. of Applied Mathematics, University College of Wales, Aberystwyth. Ken joined the Society in 1957, has served on the Council and was the President of the Society in 1974-1976. He was awarded the Society's Gold Medal Award in 1984.

RESIGNATIONS: None

DEATH

We regret to announce having received notification of the death of the following member:

Prof. L. R. G. Treloar O.B.E. of Cheshire. He joined the Society in 1942, was President for 1953-1955 and was elected an Honorary member in 1980.



Prof. Zvi Rigbi

Philip Vallentine Tobias Professor
in Glass and High Temperature Technology

פרופ' צבי ריגבי
קתדרה ע"ש פיליפ וולנטין טוביאס
לטכנולוגיה של זכוכית וטמפרטורות גבוהות

The Leaking Bucket Problem

Professor Astarita's solution (Bulletin, 28, 20, 1985) merely restates the principle of conservation of matter.

The real questions are: using Prof. Astarita's terms, how are F_A and F_B related to the rheological properties of the leaking fluid, the dimensions of the hole and the length of the column? Does a compressive stress develop over the cross-section of the bottom of the column? Can the stress along the column be determined?

Unfortunately, the original statement of the problem was not worded sufficiently carefully.

Z. Rigbi

INTERFACIAL RHEOLOGY

The Colloid & Interface Science Group of the Faraday Division of the Royal Society of Chemistry and the Colloid and Surface Science Committee of the Society of Chemical Industry are organising a joint one-day meeting on:

INTERFACIAL RHEOLOGY

at Imperial College on 19th December 1986. The topic of which will be the rheology of the fluid/fluid interface.

Full details and registration forms are available from:

Dr B J Briscoe
Dept. of Chemical Engineering and Chemical Technology
Imperial College
Prince Consort Road
LONDON SW7 2AY

**DEFORMATION IN
SOLID POLYMERS**

**Devonshire Hall - Leeds University
9th - 11th September 1986**

**The British Society of Rheology
in association with
the Polymer Physics Group of the Institute of Physics**

Dr C. P. Buckley (Department of Mechanical Engineering, UMIST) will present a sponsored lecture, also to be published in the BSR Bulletin.

The following have agreed to present papers:

Dr R. A. Duckett	- Leeds
Professor B. Escaig	- CNRS, Lille
Professor R. N. Haward	- UMIST
Dr J. M. Hutchinson	- Nottingham
Professor J. Kubat	- Chalmers UT, Goteborg
Dr N. G. McCrum	- Oxford
Professor B. Parsons	- Queen Mary College
Professor I. M. Ward	- Leeds
Dr A. H. Windle	- Cambridge

Contributed papers are invited; please send abstracts (title, name and address, abstract of 100 words, typed on A4 paper) by 1st November 1985 to:-

Mr S. T. E. Aldhouse
BP Chemicals Ltd.
Research and Development Department
Bo'ness Road
Grangemouth
Stirlingshire FK3 9XH

The University of Newcastle upon Tyne

Departments of Mechanical Engineering and Engineering

Mathematics

RESEARCH ASSOCIATE:

Active Hydrodynamic and Squeeze Film Bearings for
Vibration Control

Applications are invited for the above post, which is funded by the Science and Engineering Research Council and is tenable for a period of 18 months. The starting salary will depend upon age and experience and will be in the range £7520 to £8920.

The research is part of an ongoing programme of work on active vibration control which is being supported by the two Departments. The aim of the research is to determine the extent to which the load-carrying capacities of bearings operating with magnetic or electroviscous lubricants are changed by externally applied magnetic and electrical fields. The work is likely to be theoretical and computational in the first instance, but the feasibility of using such bearings as active dampers for vibration control will be assessed with a view to eventual practical trials.

Applicants should have a good honours or high degree in physics, mathematics or engineering. Some familiarity with the theory of hydrodynamic lubrication or with non-Newtonian fluid mechanics would be an advantage.

Applications, which must include a curriculum vitae and the names of two referees, should be sent to Dr J S Burdess, Department of Mechanical Engineering, The University, Newcastle upon Tyne, NE1 7RU. No closing date is set, but the post may be filled from 1st October 1985 or shortly thereafter. Further information may be obtained from Dr Burdess or from Dr C J S Petrie in the Department of Engineering Mathematics (Telephone 0632-328511 ext. 2230).

ADVANCES IN RHEOLOGY

Proceedings of the Ninth International Congress on Rheology, Acapulco, Mexico, October 8-13, 1984

edited by B. MENA, A. GARCIA-REJON and C. RANGEL-NAFAILE, Instituto de Investigaciones en Materiales, Ciudad Universitaria, Coyoacan, Mexico

These four volumes contain the entire proceedings of the largest rheology meeting ever held - the Ninth International Congress on Rheology, held in Acapulco in October 1984.

The meeting was addressed by some of the most eminent scientists in the field and more than 360 invited and contributed papers were presented. Covering a wide range of topics, these are published in full in four volumes:

Volume 1 - Theory

- contains the plenary lecture, invited lectures, and papers on General Theory and Numerical Analysis

Volume 2 - Fluids

- contains papers on Fluids and Suspensions

Volume 3 - Polymers

- contains papers on Solids, Melts, Blends, Polymer Processing, and Composites

Volume 4 - Applications

- contains papers on Rheometry, Food Rheology, Biorheology, and Petroleum Rheology

As these proceedings are available so soon after the congress, they provide a wealth of particularly up-to-date information not to be found in any other publication.

1984 2854 pages (4 volumes)
Set Price: US \$ 250.00 / Dfl. 825.00
Paperback
Set ISBN 0-444-99576-5



**ELSEVIER SCIENCE
PUBLISHERS**

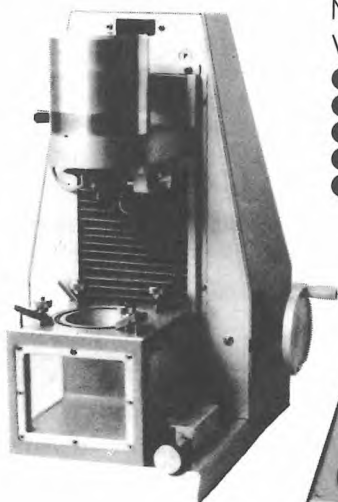
P.O. Box 211, 1000 AE Amsterdam,
The Netherlands
P.O. Box 1663, Grand Central Station,
New York, NY 10163, USA

MATERIALS TESTING FROM SANGAMO RHEOLOGY

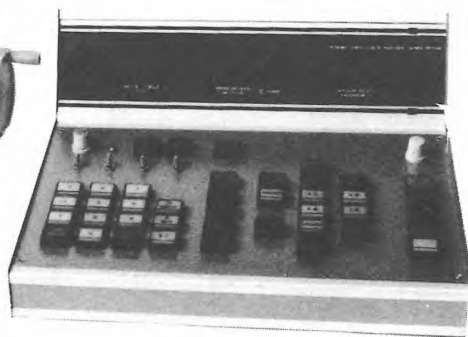
A comprehensive range of sophisticated rheology equipment for the measurement of shear, yield, thixotropic and the visco-elastic properties of Polymer Melts, Suspensions, and most Newtonian or non-Newtonian fluids.

Visco-elastic Analyser offers:

- Yield stress evaluation
- Creep growth and relaxation
- Oscillatory mode tests
- Temperature to 300°C
- With IEEE Interface and Software



Visco-elastic Analyser
Constant Stress Tester



Other Rheology products from Sangamo include:

- New Series II R20 Weissenberg now available
- Elongational Viscometer
- Rheovibron Solids Tester

Computer Controlled versions of the above available.

SANGAMO
Schlumberger

Sangamo Transducers (Rheology Division)
Steyning Way, Southern Cross Trading Estate
Bognor Regis, West Sussex PO22 9ST
Telephone 0243 825011 Telex 86827