

THE BRITISH SOCIETY OF RHEOLOGY

EXPERIMENTAL RHEOLOGY

Sessions on

Instruments; Techniques; Management

UNIVERSITY OF BRADFORD

17—19th APRIL, 1968

Hon. Conference Secretary :

DR. J. HARRIS,

Postgraduate School of Studies
in Chemical Engineering,

University of Bradford.

HAEMORHEOLOGY AND THE MICROCIRCULATION

Joint Symposium of
BRITISH SOCIETY OF RHEOLOGY
BRITISH MICROCIRCULATION SOCIETY

at

The Royal College of Surgeons
Lincolns Inn Fields, London, W.C.2

SATURDAY, 10th FEBRUARY, 1968

Joint Hon. Conference Secretaries:

B. WARBURTON,
School of Pharmacy,
Brunswick Square,
London, W.C.1.

P. A. G. MUNRO,
Anatomy School,
University of Cambridge,
Cambridge.

My sonnet

BULLETIN



BRITISH SOCIETY OF RHEOLOGY

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Hon. Editor:

Dr. D. W. HADLEY,
J. J. Thomson Physical Laboratory,
Whiteknights,
Reading,
Berks.

1968

No. 1

HAEMORHEOLOGY AND THE MICROCIRCULATION

British Society of Rheology—British Microcirculation Society

Joint Symposium, London,

10th February, 1968

During the Symposium, held at the Royal College of Surgeons, twelve papers were presented, mostly by invited authors, and in addition there were two demonstrations. The main contribution was undoubtedly in the field of the biophysics of blood flow in the smallest vessels. Solution of the equations involved often entailed the use of a computer, but during the presentation the mathematics were usually simplified for the benefit of an audience, many of whom were concerned principally with practical applications to clinical diseases.

M. J. Lighthill analysed the behaviour of a deformable pellet, such as a blood cell, whose resting maximum diameter was just too large for it to pass through a small tube, such as a capillary, without deformation. The existence of a thick film was predicted, in which there must be substantial leakback from one "bolus" to another. Reduction in velocity would cause such a film to become very thin, resulting in a temporary sticking or seizing up of the red cell's motion. This type of behaviour may often be observed in the smallest capillaries in the living circulation, but does not account for the cell deformations recorded by high speed photography.

The behaviour of large rigid simple models of the shape of resting red cells was described by S. R. Montgomery, who showed that the motion was essentially unstable unless "pores" were made in the centre corresponding to about one-tenth of the leading surface area. A mathematical analysis of pulsating flow was provided by J. H. Gerrard in the case of flow driven by simple pistons. Under these circumstances the axial velocity would be less than that nearer the wall of the tube. E. W. J. Mardles examined the behaviour of simple liquids, containing a meniscus, flowing at very low shear rates in narrow channels and showed that the resistance of this meniscus must be very great if the channel is less than 10 microns in diameter. Although this is the mean diameter of the larger capillaries it is not yet certain how these conclusions, which might apply to the plasma, would also apply to the blood cells. It has been suggested that fibrinogen in the plasma is responsible for giving whole blood its

non-Newtonian characteristics but D. N. Walder, J. P. A. Weaver and A. Evans using a cone and plate viscometer, showed that the wide range of variations in fibrinogen level that normally occurred in patients with different diseases did not appear to have any physiological effect except perhaps at very low shear rates; discussion on this point was controversial.

R. B. Whittington and J. Harkness discussed the effects of cryoglobulins in human plasma, and R. Pringle showed the results of interesting observations in patients with Raynaud's disease who had abnormal blood viscosities and flow cessation pressures. The latter phenomenon was treated in a different manner by C. G. Caro, T. H. Foley and M. F. Sudlow who provided interesting data on the effect of altering the transmural pressure in normal human subjects. The elastic behaviour of the wall of "living" blood vessels was considered by D. J. Patel and D. L. Fry. J. L. Corbett and S. H. Milton showed that dye studies on the vascularity of experimental skin flaps in animals demonstrated considerable species variability and B. A. Warren and M. C. Davey illustrated the ultrastructure of platelets and fibrin by means of electron photomicrographs.

D. H. Fox and D. Miles exhibited a working prototype instrument for measuring the yield stress of whole blood, together with illustrative records of the different behaviour of plasma, etc. They also read a paper discussing the significance of their preliminary results. The other demonstration, by T. J. Ryan, consisted of a number of excellent photographs showing clinical microscopy of the skin in different diseases and under varying conditions.

Several papers, although concerned primarily with one particular aspect of blood rheology, provided data or inferences relating to other papers which dealt with the microcirculation in human patients or normal subjects, and the symposium as a whole was valuable in bringing together workers in previously unrelated disciplines. It is to be hoped that the introductions now made will foster closer relationships than have hitherto existed. Physicists, hydraulic engineers and rheologists would learn much of the problems of the microcirculation if they were able to see living tissues and high speed photographs of blood cells in motion; and the more clinical research workers have much to learn of the methods and parameters needed before solution of the problems is likely to yield to mathematical analysis.

Discussions were free and varied, with much audience participation, and nearly always had to be limited by the chairman in order to keep the programme within the available time; indeed more time would have been an advantage. A most encouraging initial joint meeting for both Societies concerned.

P. A. G. MONRO,
B. Warburton.

NON-NEWTONIAN FLUIDS IN CHEMICAL ENGINEERING

A Symposium held by The Institution of Chemical Engineers

(N.W. Branch), Salford

12th December 1967

The following papers were presented:

1. Introductory Talk, F. A. Holland (Salford University).
2. "Agitation of Non-Newtonian Fluids", N. E. Moul (Lightnin Mixers).
3. "The Application of Helical Gear Pumps to the Handling of Non-Newtonian Fluids", G. Carter (Mono Pumps).
4. "Flow of Generalised Bingham Fluids in Straight Pipelines", D. C. H. Cheng, J. B. Davis and A. Scarrow (Warren Spring).
5. "The Characteristics of Helical Ribbon Impellers in Viscous Liquids" Part I, Flow Patterns. J. R. Bourne and H. Butler (Nottingham University).
6. "Heat Transfer to Agitated Non-Newtonian Fluids", J. Pollard and T. A. Kantyka (I.C.I., Dyestuffs).
7. Heating and Cooling Non-Newtonian Liquids in Pipes, D. R. Oliver (Birmingham University).

Professor Holland's paper provided an introduction to the subject of non-Newtonian behaviour for delegates unfamiliar with the subject, and a refresher for those who had not recently dealt with the flow of non-Newtonian fluids. The concepts of Newtonian and non-Newtonian viscosity, and definitions of pseudo-plastic, Bingham plastic, dilatant, thixotropic and rheopectic fluids were discussed initially, to be followed by derivation of the equations for laminar pipe flow. The power law and more complex rheological models were introduced and their usefulness in pipe flow calculations was assessed.

The use of the slope of the tangent to the curve when $\log_{10} \Delta P \cdot d_i/4l$ is plotted against $\log_{10} 8u/d_i$ for pseudoplastic and dilatant fluids in the calculation of pressure drop—flow rate relationships for non-Newtonian fluids (not restricted to power-law model fluids) was clearly shown. Turbulent friction factor calculation was considered, and in closing, the practical applications of non-Newtonian fluids were briefly dealt with. Discussion centred on the shear rates obtained with non-Newtonian fluids in mixers. Professor Holland then acted as chairman for this Symposium.

Mr. Moul began by outlining the principal types of non-Newtonian behaviour and then defined the requirements for agitation, and classi-

fied mixing duties as: (1) blending of similar viscosity fluids; (2) incorporation of low viscosity fluids; (3) heat transfer.

A system of classification for impellers was outlined, with the open impeller being suitable for Newtonian liquids up to 50,000 centipoise, and for most non-Newtonian liquids up to 10,000 centipoise. The best impeller for more viscous non-Newtonian liquids is one which sweeps most of the vessel, such as a helical-blade impeller. Turbine impellers are used for Newtonian liquids up to viscosities of 100,000 centipoise. For power-law non-Newtonian liquids, a log plot of apparent viscosity against rotational speed was referred to, giving parallel straight lines. This permitted speed of rotation for various impellers to be related to rotational viscometer data. The author showed a number of slides demonstrating the practical solution to mixing problems with non-Newtonian fluids. Questions in the discussion related to the importance of pilot plant tests and scale-up, and to optimum impeller position in a cylindrical vessel.

The main types of positive displacement pumps were summarised by G. Carter, and their limitations noted. Essential features of the Mono helical gear pump were then discussed. The effects of apparent viscosities between 1-6 poise and up to 500 poise on pump performance characteristics were discussed with particular reference to the decreased mechanical slip occurring with increasing fluid viscosity. The estimated rates of shear within the pump elements allowed an indication to be given of the probable effects for liquids having dilatant or pseudo-plastic viscosity characteristics. Guidance on the selection of pump operating speed to contend with higher apparent viscosities and varying degrees of abrasion for suspensions were related to fluid and rubbing velocities within the pump element by means of graphs. Finally some typical pump applications and recent developments were described.

Dr. Davis showed how published results of pipe flow had been combined so that both laminar and turbulent flow of generalised Bingham fluids could be predicted, using an equation $\tau = \tau_y + K\dot{\gamma}^n$, in which τ_y , K and n were constants, τ and $\dot{\gamma}$ being shear stress and shear rate respectively. Methods of determining the constants were discussed. The flow rate for a specified pressure gradient was evaluated using a computer, and data were produced covering wide ranges of pipe diameter, pressure gradient and fluid properties. Flow rates covered a range far beyond practical interests, with linear velocities up to 50,000 ft./sec. at extremely high Reynold's number.

In discussion it became clear that interpolation from the tables could be dangerous, and use of the computer program with appropriate inputs was recommended; the program was available in the preprint, written in Algol. The advantage of a computer program over a set of charts (suggested in discussion) was the greater accuracy for single values, and the speed with which a series of flow rates for a large number of different conditions could be calculated.

The question of designing large crude-oil pipelines from concentric cylinder viscometer data was raised. In reply to a question on thixotropy Dr. Davis said equilibrium values for K and n should be used, as these were correct with the prolonged shear of steady flow in long pipes.

Propeller and turbine impellers are often unsuitable for mixing liquids having viscosities of more than a few hundred poise. The helical ribbon, with its small clearance between ribbon and wall, increases the proportion of liquid agitated effectively and consumes less power. Dr. Bourne described experiments on power consumption and flow patterns for five helical ribbons used with mixing tanks of widely differing sizes. The velocity distribution in the stirred liquids was indicated either by air bubbles or small plastic spheres. Below a Froude number of 0.01, the flow pattern was determined by the pumping effect of the ribbon, but secondary flows developed at higher speeds. In the primary flow region, dimensionless axial velocities in the core and between the blades and the rate of fluid circulation were all independent of fluid type and viscosity, stirrer speed and scale. These observations were explained by an approximate theory for the pumping capacity of the helical ribbon. This indicated an optimum ribbon angle of 45° , which is considerably greater than has been used in all published work.

Mr. Kantyka described the measurement of jacket and coil heat transfer coefficients in vessels with anchor agitation. Results for non-Newtonian materials were correlated with data for Newtonian fluids by using average shear rates derived from agitator power measurements.

In the final paper Dr. D. R. Oliver explained that, owing to the high viscosity of most non-Newtonian liquids, they were usually processed in laminar flow. It was emphasised that the heat transfer rate changed little as a result of the presence of non-Newtonian properties; for pseudoplastic fluids there was an increase of some 5 to 20 per cent, dependent on the degree of pseudoplasticity. The Pigford-Metzner equation satisfactorily predicted the heat transfer when heating the liquid but was less satisfactory for cooling; the error seemed to lie in the correction factor allowing for the change in effective viscosity with position within the tube.

The effects of natural convection were discussed. Normally, the heat transfer rates were increased, but for some types of non-Newtonian liquid a decrease was observed. It was suggested that this was due to the formation of a layer of liquid, of "viscosity" higher than that of the bulk fluid, which effectively blanketed a fraction of the internal area of the tube.

It was explained that secondary flow patterns might be developed when the liquids possessed appreciable elasticity and the tubes were of non-circular cross-section. A quarter-inch diameter copper tube,

flattened to produce a cross-section with ratio of major to minor axis of 2 to 1, gave a higher heat transfer coefficient even for Newtonian solution (due to the increase of mean wall shear rate), but for viscoelastic Polyox solutions a further increase of some 30-40 per cent was achieved. It was suggested that secondary circulation patterns might have been responsible for this behaviour.

During the discussion following this paper Dr. Oliver emphasised that the increase in heat transfer with flattened tubes was due to secondary flow. The increase could be obtained only in laminar flow of highly viscoelastic Polyox solutions. Previous workers had failed to find secondary flows with CMC and carbopol solutions. Practical heat exchanger design was unexplored, but for plate-type heat exchangers involving highly viscoelastic fluids an increase in overall coefficient appeared possible.

This report has made as full a use as feasible of the author's own review. Full reprints of all papers but number 6 may be borrowed from the Editor, B.S.R. Bulletin.

C. B. DUCKHAM
(Salford University).

CHANGES IN COUNCIL

Mr. A. Graham has resigned from the Council, since he no longer feels able to devote sufficient time to the activities of the Society. In 1967 Mr. Graham moved from the National Gas Turbine Establishment to take up a senior research post at Imperial College, and is also writing a book on his well-known unified phenomenological theories of mechanical properties of metals and polymers.

Under the Constitution, Council may co-opt another member to fill any vacancy arising between Annual General Meetings. Dr. M. F. Culpin has kindly agreed to rejoin the Council as a co-opted member, and has also accepted the post of Conference Secretary for the 1968 September Conference.

A CHAIR IN RHEOLOGY

All members will wish to congratulate Dr. A. S. Lodge, at present Senior Lecturer in Rheology, Department of Mathematics, The University of Manchester Institute of Science and Technology, on his appointment as Professor of Rheology in the University of Wisconsin, Madison, Wisconsin, U.S.A. Dr. Lodge's post, which is held jointly in the Department of Engineering Mechanics, the Engineering Experiment Station, and the Mathematics Research Center, U.S. Army, is believed to be the first chair of rheology anywhere.

From September, Professor Lodge's address will be Mathematics Research Center, U.S. Army, University of Wisconsin, Madison, Wisconsin 53706, U.S.A.

America's gain is a loss to British rheology. Dr. Lodge is not only an outstanding scientist and a stimulating lecturer, but has a long record of service on behalf of our Society.

THE NEXT BULLETIN

All entries in Rheology Abstracts dealing with the properties of fluids are now classified using a system devised by a joint B.S.R.-I. Chem. E. working party. Descriptions of this scheme and of two other information retrieval systems of interest to rheologists will appear in the next number of the Bulletin, due for publication in less than two months' time.

To place these descriptions in context, and to indicate some further aids to survival in the overwhelming deluge of scientific publications, it has been decided to devote the whole, enlarged, issue of the Bulletin to the topic of Information Retrieval. Other articles in hand, or promised, include "Information retrieval and what to do about it" by Wilfrid Ashwell (I.C.I. Fibres and A.S.L.I.B.), a description of some of the activities of the National Lending Library for Science and Technology, and papers by William Wiswesser (U.S.A.) and Alfred Yanez (France).

If the response of members to special numbers of the Bulletin is favourable it is hoped that more single topic issues will follow. In the meantime single articles, or conference reports, on subjects of rheological interest are always required; any offers or constructive suggestions should be sent to the Editor.

ANNUAL CONFERENCE 1968

Three principal factors combined to make last year's Annual Conference one of the most successful and enjoyable ever: a wide-ranging subject; the choice of Shrivenham as a venue; and the efforts of Mike Culpin as Conference Secretary.

This year we confidently anticipate a repeat performance of that success, since all three parameters have been held constant: Mike Culpin has once more agreed to act as Conference Secretary; Professor Charlesby has arranged for Shrivenham to be available at the required time; and the theme of "Rheological Effects in Materials Under Alternating Stress" gives scope for all interests. It is intended that the discussions should cover *any* material, stressed at *any* frequency, and papers are invited, suitable for presentation as a half-hour talk. Synopses should be sent by 1st May to: Dr. M. F. Culpin, 8 Broadway, Pontypool, Mon., NP4 6HN.

The conference will be held on three days within the period 9th-12th September, 1968, at the Royal Military College of Science, Shrivenham, Swindon, Wilts. Application forms for attendance will be sent to all members in due course.

A Conference at Shrivenham can be recommended even for those who do not wish to attend a single formal session. The large, comfortable, lounges and bars are ideal for informal (and inexpensive) discussions and chats, and at what other conference venues do all delegates have the services of a batman. Above all, Shrivenham ought to be remembered for its gastronomic delights. The normal standard is that of a very good hotel, whilst a Conference Dinner has always been equal to anything noted in the Good Food Guide.

NEWS FROM FRANCE

The Committee of Groupe Français de Rhéologie has proposed an interesting change in the Groupe's Constitution. The proposal is that the retiring President shall remain an *ex officio* member of the Committee for three years.

Two further definitions of rheological terminology have been received, and literal translations are given below.

79. *Coefficient de frottement intérieur.* In a harmonic experiment where deformation ε is imposed (sinusoidal), let ε_m be the amplitude of oscillation of the deformation, σ_i the value of the stress when $\varepsilon = \varepsilon_m$, ΔW the area of the cycle and $W = \frac{1}{2} \sigma_i \varepsilon_m$. The coefficient of internal friction at the imposed deformation is $f_e = \Delta W/W$.

If the stress σ is imposed (sinusoidal), let σ_m be the amplitude of oscillation of the stress, ε_i the value of the deformation when $\sigma = \sigma_m$, ΔW the area of the cycle and $W^1 = \frac{1}{2} \varepsilon_i \sigma_m$, the coefficient of internal friction at the imposed stress is $f_o = \Delta W/W^1$.

σ_i or ε_i are to be measured from the centre of the cycle. In the case of linear behaviour, if ϕ is the loss angle, M_c the storage modulus, one has: $\sigma_i = \sigma_m \cos \phi$, $\varepsilon_i = \varepsilon_m \cos \phi$, $\Delta W = \pi \sigma_m \varepsilon_m \sin \phi$

$$W = W^1 = \frac{1}{2} \sigma_m \varepsilon_m \cos \phi = \frac{1}{2} M_c \varepsilon_m^2$$

whence: $f_e = f_o = 2\pi \tan \phi$

$W/2$ is in this case the average elastic energy throughout a complete cycle.

80. *Coefficient de frottement interne. Angle de frottement interne.* For certain materials, in which plastic deformation or rupture are produced when the shear stress τ on a surface element exceeds a critical value, τ is a linear increasing function of normal stress v (counted positive following the interior normal): $\tau = av + b$.

a is called the *coefficient de frottement interne* (English equivalent not known). If one puts $a = \tan \psi$, ψ is the *angle de frottement interne* (English: angle of effective friction, or angle of shearing resistance), b is called cohesion in soil mechanics.

All 80 definitions so far approved will shortly be published (in French) in Cahiers du G.F.R.

BOOK REVIEWS IN RHEOLOGY ABSTRACTS

Mike Culpin, amongst many other tasks, organises the Book Review section of Rheology Abstracts. He finds that he is having to undertake most of the reviewing himself, and would like to hear from any member who is willing to take over these duties, or give a helping hand. In addition, he would like to know details of any particularly good books in the rheological field which have not been noted in Rheology Abstracts. Please communicate directly with Dr. M. F. Culpin, 8 Broadway, Pontypool, Mon., NP4 6HN.

POET'S CORNER

Dr. George Scott Blair was interested to see that verse was now printed in the Bulletin, and submitted the following sonnet, written when, as a young rheologist (before the term "rheology" existed) he left a job involving work with flour suspensions to go to Rothamstead to work on soils.

TO MY OSTWALD VISCOMETERS

Distance, indeed, lends charm to you, my friends
As in your thermostat at rest you stand
No longer can I shake you by the hand
Nor clean with "aqua fort." your graceful bends.
No longer can I tell of Einstein's fame
Nor, theorising on viscosity
with colloid-chemical verbosity
Delight to speak von Smoluchowski's name.
Do you, unchanging ones, whose water-times
Remain the same, though men may come and go,
Despise us mortals of uncertain toil?
And, in your pseudo-constancy sublime,
Laugh (on your holiday from streamline flow)
Perchance at me, who changed from flour to soil?

G. W. S. B., 1926.

The Editor invites members to submit *short* pieces of verse for publication in future Bulletins. Any verse form may be used (even Limericks), provided that the work is neither libellous nor indecent. No prizes offered.

NOTES AND NEWS

We were sorry to hear that Professor Markus Reiner sustained a broken leg as the result of being run down whilst crossing a busy road. Professor Reiner is now, however, well on the way to recovery, and is able to walk once again. We send to Professor Reiner our best wishes for a complete and speedy recovery, and hope to see him in Britain again in the near future.

It appears improbable that there will be enough support to arrange reduced rate air travel from Britain for the International Rheology Congress in Japan, October 1968. Nevertheless a final attempt will be made to recruit the necessary 15 passengers, who must be members of the Society of at least six months' standing. Will any member who is interested in flying to Japan in October please contact the Editor before 10th May, if he has not done so already.

The Second International Conference on Fracture will be held at the Metropole Hotel, Brighton, from 13th–18th April, 1969. Further details will be available in June, 1968, and are obtainable from Mr. F. K. Pyne, A.E.R.E., Harwell, Didcot, Berks.

The British Geotechnical Society will hold a conference on "In Situ Investigations in Soils and Rock" in London, 13th–16th May, 1969. Problems considered will include both mechanical and water flow behaviour. Offers of papers, and all enquiries, should be addressed to The Secretary, British Geotechnical Society Conference, Institution of Civil Engineers, Great George Street, London, S.W.1.

The Institute of Physics has announced the following conferences of interest to rheologists. "Stresses in Composite Materials", Cranfield, 25th–27th September, 1968; "Physics in the Metal Forming Industries", Harrogate, 19th–21st November, 1968. Further information from The Meetings Officer, 47 Belgrave Square, London, S.W.1.

Papers are sought for a symposium entitled "Tribology in Railways", to be held in London 19th–20th February, 1969. Further information from The Secretary, Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

The Instrument Society of America is holding a conference on "New Technologies in Instrumentation", New York, 28th–31st October, 1968. Details from Mr. O. W. Williams, 530 William Penn Place, Pittsburg, Penn. 15219, U.S.A.

OBITUARY

The death occurred on 8th January of Mr. C. C. Wood, of 19 Gilpin Green, Harpenden, Herts. Mr. Wood was a former Deputy Head of Pharmaceutical Research, Allen and Hanbury Ltd., Ware, and had been a member of the Society since 1943.

New Members

NAME AND ADDRESS	INTERESTS
C. T. Cowan, Ph.D., A.R.I.C., 29 Parkhurst Rd., Horley, Surrey. A.P.V. Co. Ltd., Manor Royal, Craw- ley, Sussex.	General, metals, polymer solutions, foodstuffs, biorheology.
D. C. Evans, B.Sc., Roscoe Hall, Green Bank Lane, Liverpool 17. Appl. Maths. Dept., University of Liverpool, Liverpool 3.	Theory, polymer solutions, bio- rheology.
B. M. Hiorns, B.Sc., Barn House, Pengam, Mon. Dept. of Chem. Engng., University of Birmingham, Birmingham 15.	General (expt.), polymer solutions.
F. Hoyle, C.Eng., F.P.S., A.M.I. Chem.E., 57 The Grove, Hipperholme, Halifax, Yorks. John Mackintosh & Sons Ltd., Albion Mills, Halifax.	Confectionery.
M. J. King, B.Sc., 6 Harringay Ave., Liverpool 18. Appl. Maths. Dept., University of Liverpool, Liverpool 3.	General (theory).
B. Martin, B.Tech., Churchill College, Cambridge. Dept. of Chem. Engng., University of Cambridge.	General (theory and expt.), rubbers, polymers, polymer solutions.
A. W. Preece, B.Sc., Ph.D., 8 Tamwell, Upper Stanton Drew, Bristol. Dept. of Child Health, University of Bristol, St. Michaels Hill, Bristol 2.	Biorheology.
F. G. Petronio (Professor), Via dell' Università 13, Trieste, Italy. Univ. degli studi di Trieste, Ist. di Meccanica, Piazzale Europa 1, Trieste.	All aspects of rheology.

UNIVERSITY OF BRADFORD
POSTGRADUATE SCHOOL OF STUDIES IN CHEMICAL
ENGINEERING
RESEARCH FELLOWSHIP

Applications are invited for the post of Research Fellow to join a team working on the behaviour of non-Newtonian fluids.

Initially the work would be concerned mainly with the experimental characterisation of a wide variety of non-Newtonian materials using a rheogoniometer and also the jet thrust technique. Work on specific problems of industrial significance is also being developed.

Applicants should be graduates in Engineering, Science or Mathematics and should preferably have a Ph.D. or equivalent experience, although candidates without such experience, particularly those expecting to complete their Ph.D. work this year, are also invited to apply.

The Research Fellowship will be tenable for 3 years at a salary in the range £1,470 to £1,920.

Enquiries giving brief details of qualifications and experience should be made to Professor Wilkinson, Postgraduate School of Studies in Chemical Engineering, University of Bradford, Bradford 7.

Mechanical Properties and Design

It is proposed to hold a meeting to consider those properties of solids which cannot be represented by the classical elastic theory. It is hoped to consider not only the properties themselves but also the implications of those properties when the materials are used in practical applications. Many materials of potential importance, such as plastics, are not being used to full advantage because of a lack of understanding of their mechanical properties and because, therefore, there are no adequate design procedures for the calculation of component dimensions. Even conventional materials, when used outside their normal working range display characteristics that demand special consideration, as in metals under load at elevated temperatures. Composite materials and structures have assumed increasing importance in recent years, but their behaviour when subject to mechanical loads is still not adequately understood. Brittle materials can be used with confidence and safety, provided that their fracture properties are properly characterised and the principles which govern their responses properly applied.

These are the kinds of topics that it is proposed to discuss at the meeting to be held in the new University of Surrey buildings at Guildford at Easter 1969. Offers of contributions should be made by 31st October, 1968, to either R.W. Whorlow, Department of Physics, University of Surrey, Battersea Park Road, London, S.W.11, or to J.P. Berry, Rubber and Plastics Research Association, Shawbury, Shrewsbury, Shropshire.

Practical Rheology in Polymer Processing

This conference is being organised jointly by the Society and the Plastics Institute, with the aim of bringing together those concerned with polymer processing at a practical level and those making a more theoretical approach to the subject. It is hoped that papers from both groups of workers will be read and will include discussions of extrusion, film making, injection moulding, calendering, etc. as well as of test methods.

An organising committee including Mr. D.R. Reid (BXL Plastics Industrial Products Group), Dr. E. Howells (ICI Ltd., Runcorn), Mr. B.S. Glyde (Bakelite Xylonite Ltd.), and Mr. R.W. Whorlow (University of Surrey), has been set up and provisional arrangements have been made to hold the conference in London on April 17th and 18th, 1969.

Offers of papers, preferably with a synopsis, should be sent by June 30th, 1968, to Mr. R.W. Whorlow, Department of Physics, University of Surrey, Battersea Park Road, London, S.W.11, or to any other member of the organising committee.

The University of Wales Institute of Science and Technology has announced two courses of possible interest to members.

5 July, 1968. "Condensation Polymers" (The science and technology of some established materials will be given, as well as results on newer materials designed for special applications).

18-19 September 1968. "Electrical Properties of Polymers" (The conference will cover experimental and theoretical studies of dielectric behaviour and breakdown, and d.c. conductivity).

Details from: D.R. Hub, University Institute, 22 North Road, Cardiff, CF1 3DY.

The Concrete Society and the University of Southampton are sponsoring an International Conference on "Structure, Solid Mechanics and Engineering Design in Civil Engineering Materials", to be held 21-25 April 1969. There will be three main sections, dealing with (a) Internal structure and micromechanics; (b) Structure and mechanical properties; (c) Engineering design. Further information from: M. Te'eni, Department of Civil Engineering, The University, Southampton SO9 5NH.

The "Second International Conference on Fracture" will be held at Brighton 13-18 April 1969. The Assistant Conference Secretary is Mr. F.K. Pyne, A.E.R.E., Harwell Didcot, Berks.

The Royal Microscopical Society is holding an International Meeting on "The Microstructure of Materials" at Oxford 16-19 September, 1968. There will be sessions on polymers and fibrous materials, metals, ceramics, and electronic materials. Details from: The Executive Secretary, Canterbury House, 393 Cowley Road, Oxford.

The April 1968 issue of "Bulletin du G.F.R." contains a 10 page summary of some of the rheological work in progress in France in 1967. A copy of the report may be borrowed from the Editor.

B.S.R. News

Council has approved a scheme for reclassification of members' interests, full details of which will appear in a forthcoming Bulletin. The new scheme is based primarily on materials, and will indicate whether rheology is the main interest of a member, and whether the rheological concern is with basic principles or technological applications.

The scheme will be incorporated in new Membership Application Forms, and a questionnaire will be sent to all present members to gather the required information before the publication of the next Membership List.

A competition for a Gold Medal for Applied Rheological Research will be held in 1969, the closing date being 1 April. Rules will be published in a forthcoming Bulletin, but further information can be obtained from: Dr. J.P. Berry, Rubber and Plastics Research Association, Shawbury, Shrewsbury, Shropshire.

Applications are invited for a post as Post Doctoral Research Fellow in the Department of Chemistry, University of Wales Institute of Science and Technology, for work on Organic Gels, in collaboration with Dr. G.S. Park.

Salary Scale £1,105 - £1,340 with FSSU.

Further particulars from the Deputy Registrar (Personnel), University of Wales Institute of Science and Technology, Cathays Park, Cardiff.

STOP PRESS SUPPLEMENT No. 4, 1967

UNIVERSITY OF WALES INSTITUTE OF SCIENCE AND TECHNOLOGY (designate)
Department of Chemistry. Immediate applications are invited for a post
as POST DOCTORAL RESEARCH FELLOW for work in collaboration with
Dr.G.S. Park, Reader in Chemistry, on ORGANIC GELLS. This work
is to be part of a project financed under a Ministry of Defence Grant.
The appointment is in the first place for a period of one year, but can
be expected to be renewed for a period of two further years. Salary scale:
£1,105 x 75 to £1,180 x 80, to £1,340 with F.S.S.U. For forms of
application please apply to the Deputy Registrar (Personnel), University
of Wales Institute of Science and Technology (designate), King Edward
VII Avenue, Cathays Park, Cardiff.

UNIVERSITY OF SURREY, Department of Physics. Course of 8 Lectures on
DYNAMIC MEASUREMENTS IN RHEOLOGY, Wednesdays 6.30 - 8.30 p.m., commencing
10 January 1968. Lecturers: M. Braden and R.W. Whorlow.
Syllabus: Methods of measurement of creep, stress relaxation and response
to sinusoidal stress. Wave propagation in lossy media. Relaxation and
retardation times. Superposition principle. Inter-relationships of
relaxation and retardation time spectra with creep, stress relaxation
and dynamic test data using precise (transform) and approximate methods.
Spring-dashpot and electrical analogues.
Enrolment forms may be obtained from the Secretary (Short Courses,
University of Surrey, Battersea Park Road, London, S.W. 11.).

IUPAC is organizing a symposium on Macromolecular Chemistry in Toronto,
Canada, from 3-6 September 1968. The theme will be structure and
properties of macromolecular systems: synthetic, natural and biological.
Further information from Organizing Committee, Box 932, Terminal A,
Toronto, Canada.

The British Theoretical Mechanics Colloquium will hold a meeting at Oxford, 2-5 April 1968. In addition to discussion papers there will be invitation lectures by Prof. G. Carrier (Harvard), Prof. W.S. Hemp (Oxford) and Prof. J.T. Stuart (I.C.). Information from Dr. A.B. Tayler, Mathematical Institute, St. Giles, Oxford.

The Editor has available for loan copies of the abstracts of papers presented at the symposium on Non-Newtonian Flow, held at Salford University, 12 December 1967. The speakers were: Professor F.A. Holland (Salford U.) ; Mr. N.E. Moul (Lightnin Mixers); Mr. G. Carter (Mono Pumps); Dr. D.C.H. Cheng (Warren Spring); Dr. J.R. Bourne (Nott. U.); Dr. D.R. Oliver (B'ham U.); Mr. J. Pollard (I.C.I.).

Would any members interested in the possibility of a reduced rate air fare to Japan for the International Rheology Congress please contact the Editor as soon as possible, if they have not already done so.

A joint meeting of the Society and the Plastics Institute will be held in Spring 1969 in the London area. The subject of the meeting will be "Practical Rheology in Polymer Processing". It is hoped to bring together those concerned with practical processing problems and those attempting more fundamental investigations. Offers of papers may be sent in the first instance to: Mr. R.W. Whorlow, Dept. of Physics, University of Surrey, London, S.W.11.

The Society is again collaborating with the National Engineering Laboratory in the preparation of a survey of rheological research in progress in Britain.

In order to reduce the amount of work involved it is not intended this time to circularise all research establishments and members of the Society. Instead, all the contributors to the 1966 survey have been invited to revise their previous entries, and to suggest additional workers who are known to have entered the field since 1966.

If any members of the Society who were not included in the previous survey would like to be included in the current survey (or if they have any colleagues in this position) they are invited to contact the writer, who will be pleased to send them some forms on which to report their present research interests.

A.T.J. Hayward, National Engineering Laboratory, East Kilbride, GLASGOW.

A conference on "Time dependent effects in polymeric solids will be held at Bradford, 10-11 May, 1968. Details from: The Registrar, University of Bradford, Bradford 7.

The Deutsche Rheologische Gesellschaft is holding its Annual Conference in Berlin, 20-22 May 1968. There will be sessions on: Rheometry; Properties and behaviour of visco-elastic materials; and Rheology in process technology. Information from D.R.G. at Geschäftsstelle, 1 Berlin 45, Unter den Eichen 87.

A symposium on "Polymers in Space Research" will be held in Pasadena, California, 15-17 July 1968. One day will be devoted to each of the following topics: Developments in thermally stable and ablative polymers; Polymers at cryogenic temperatures; Solid propellants. Further information from: Alan Rembaum, Jet Propulsion Laboratory, Cal. Tech., 4800 Oak Grove Drive, Pasadena, California 91103, U.S.A.

Abstracts of the Winter Meeting of the (U.S.) Society of Rheology, held 5-7 February 1968, may be borrowed from the Bulletin Editor.

University of Reading, Department of Applied Physical Sciences.

A vacancy exists for a research student to work on the rheological properties of liquids subjected to severe transient stresses. Candidates should have, or expect to obtain during 1968, a good Honours Degree in Physics, Chemistry or Materials Science. The terms of the grant are equivalent to a S.R.C. studentship, and the holder would be expected to work for a higher degree. Apply to Dr.W.Hirst, Dept.of Applied Physical Sciences, University of Reading, Whiteknights, Reading, Berks.