

BULLETIN



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Hon. Editor:

M. CAMINA,

Paint Research Association,

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FOREWORD

The Bulletins from the 1941 Club Notes to the 1977 edition have been bound in eight volumes. Each volume covers the years

1941—1944	1945—1949	1950—1953
1954—1957	1958—1966	1967—1969
1970—1973 and	1974—1977	

There are unfortunately three different sizes, the first volume is 14in. x 8½in., the next three are 9½in. x 7in. and the last four 8½in. x 5½in., which is the size they will continue to be bound unless the size of the Bulletin is changed.

Browsing randomly through the volumes, I have encountered numerous snippets of interesting information. The subscription to the British Rheologists Club in 1941 was 25p (5/-), raised in 1945 to £1 and in 1972 to £2. In spite of present inflation there is no intention of raising the fees.

In June 1941, the Bulletin reported that "John O' London's Weekly" carried an article entitled "Rheology—A New Science". The comment on the article was that many club members would wish they knew as much about thixotropy as the author would have us believe is in fact known.

OFFICERS AND MEMBERS OF COUNCIL, 1978-1979

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RHEOLOGY AND RHEOMETRY IN MULTI-PHASE SYSTEMS

Plymouth, 6th-8th September, 1978

"Multi-phase Systems" is a broad topic bringing together rheologists working with a wide range of materials, and theoreticians interested in the behaviour of model composition and suspensions. This was the case at the B.S.R. annual conference held last year at the College of St. Mark and St. John of Plymouth Polytechnic. The contributed papers dealt with such materials as cement pastes, concrete, glass filled polymers, blood, sewage sludges and "red mud" from bauxite extraction. These are generally difficult systems to examine by conventional techniques because of the effects of phase separation, settlement and boundary slip. Discussion and resolution of these difficulties made this an interesting and useful conference for rheologists.

Dr. R. F. M. Robbins, the Director of Plymouth Polytechnic, welcomed the participants. The Polytechnic has cultivated a particular interest in Rheology, and may soon be the first Polytechnic to appoint a Reader in Rheology. Dr. J. J. Benbow, the retiring President of the B.S.R., gave the opening address, "Exploitable similarities in the flow behaviour of two phase materials". His theme was the similarities which occur at similar phase ratios in the behaviour of systems which may be far removed from each other in chemical constitution. Similar phenomena occur during the extrusion of a wide variety of paste-like materials, enable simple scaling laws to be applied to estimate the output of extruders handling such materials.

The papers were organised into six sessions and will be reviewed in these terms.

Fluid Systems

Dr. D. C. Cheng (Warren Spring Laboratory) introduced this session with an authoritative review of methods for measuring the viscosity of settling suspensions. Of particular interest were techniques applicable to turbulent flows in which settling was prevented. D. Eagland (School of Pharmaceutical Chemistry, University of Bradford) presented a paper by himself, G. M. Wardlow and A. P. Allen on a low shear viscometer using a very long coiled capillary, used for studying the flow properties of Polystyrene suspension in water-alcohol mixtures. Secondary flows can occur in coiled tubes giving rise to apparent Non-Newtonian behaviour. J. Austin (Department of Applied Mathematics, Aberystwyth) discussed flows in curved channels for liquids with distinct stress-strain rate relation above and below a critical stress.

Soft Systems

This session was concerned with biological systems and foodstuffs. P. A. Arundel (I.C.I. Pharmaceutical Division, Alderley Park) discussed the factors affecting the viscosity of whole blood, particularly its flow behaviour in the capillaries of living organisms. The red cells are of the same order of size as the capillary diameter, and the flexibility of their membranes and tendency to cluster can be of greater importance than the viscosity of the plasma. Some interesting shear rate and temperature effects were described.

W. M. Marrs and G. S. D. Weir described a new, accurate and versatile penetrometer for measuring the texture of foodstuffs. Dr. J. F. V. Vincent (Department of Zoology, Reading University) described the remarkable extensional properties of the ovipositor of the female locust, and its relation to its internal structure—chitin fibres embedded in a soft protein gel. An analogy was drawn between its stress-strain behaviour and the Mullins effect in filled rubbers.

Paste-like Systems

D. V. Boger (Department of Chemical Engineering, Monash University) (paper by D. V. Boger, G. Sarmiento, C. Tiu and P. H. T. Uhlherr) described the problems of pumping "red mud", a fine particle suspension arising from bauxite extraction. Proposals to pump this material at higher solid content required a study of its rheological properties and its flow regime in pipes which is affected by slip and shear history. A similar need for basic flow data to make a rational choice of pump and pipe line sizes prompted a study of the rheology of primary sewage sludge by S. N. Battacharya and M. Thompson (Melbourne Institute of Technology, Department of Chemical Engineering).

The rheological properties of cement pastes are not easily measured by conventional techniques and very coarse grained mixtures, such as concrete are more difficult still. These problems were addressed in papers by S. J. Bloomer and G. H. Tattersall (Building Science Department, University of Sheffield) who described an interrupted helical blade mixer plastometer for concrete and C. R. Dimond of the same department who compared the behaviour of cement pastes in five different rheometers.

Dr. V. vom Berg (Aachen University) gave a comprehensive account of factors influencing the rheology of cement pastes. A similar study by T. E. R. Jones and S. Taylor (School of Mathematical Sciences, Plymouth Polytechnic) included the study of a "mini concrete" using small aggregate particles in smaller scale rheological test equipment.

Fibre Filled Polymers

D. H. Thomas (Raychem, Swindon) discussed the rheological problems associated with the manufacture and use of "dough moulding" (glass filled polyester) compounds. Fibre alignment plays a major role in determining the flow behaviour during moulding and the strength distribution in moulded articles. Parallel plate shear rheometer studies were made on pre-aligned samples to determine the form of the constitutional flow relations. An instrument suitable for plant control was described.

A paper by R. J. Crowson, M. J. Foulkes and D. W. Saunders (Department of Materials, Cranfield) on the rheology of glass filled thermoplastics described similar effects which occur during injection moulding. Fibre alignment can produce major changes in flow geometry at die entries.

Rubbery Systems

L. F. Nielsen (Building Materials Laboratory, Technical University of Denmark) reviewed theories of the effect of phase ratio and phase geometry on the electric properties of two phase systems. This provided a useful introduction to the paper by A. R. Ramos and R. E. Cohen (Department of Chemical Engineering, M.I.T.) which dealt with blends of butadiene-isoprene diblock copolymers with the corresponding homopolymers. Dynamic elastic measurements were used to determine the micro-phase structure of the blends.

Poster Session

A "poster session" on general rheological topics was an interesting innovation. M. M. Cross (I.C.I. Organics Division, Blackley) discussed a general relation between shear thinning and the product of shear rate and relaxation time for several polymer systems. This enables relaxation times and shear moduli to be determined from viscosity shear data. J. M. Davies (Plymouth Polytechnic) described experiments in which capillary flow took place with a combination of steady and pulsating pressure. The enhanced flows and its frequency dependence may provide criteria for testing the applicability of different visco-elastic models. C. Klasm and J. Kubat (Department of Polymeric Materials, Chalmers University of Technology, Gothenburg) described the measurement of electrical noise during capillary and couette flow of aqueous solutions. The noise intensity seems greater for Non-Newtonian systems. T. E. R. Jones and G. Archer (Plymouth Polytechnic) described rheological measurements on mucus removed from the skin of the common eel and changes caused by treatment with traces of metallic salts and enzymes.

Stretching Flows

D. R. Oliver and R. C. Ashton (Department of Chemical Engineering, Birmingham University) have used shape convergent nozzles to produce high rate extensional flows in polymer-thickened oils, elastic effects being measured by the Jet-thrust technique. Four different types of oil were measured at temperatures up to 80°C. J. Harris (Unilever Research, Sharnbrook, Bedfordshire) showed the value of convergent nozzle flow measurements for measuring the extensional viscosities of "awkward" material, particularly foodstuffs, which give problems in conventional viscometers because of wall slip or phase separation.

A cine-film by D. V. Boger (Monash University) showed the remarkable changes of flow regime which took place with increasing flow rate of a viscoelastic liquid entering a capillary with a conical entry from a larger diameter chamber. Apart from the familiar pulsating and spiral flow regime, inertia effects gave rise to convergent-divergent flows in the entry regime. In an extreme case this produced a stationary cavitation bubble immediately in front of a blunt capillary, with the polymer solution flowing around it!

The extra-curricular activities of the conference included visits to Cotchele House and to English China Clays Lovering Pochin Ltd. at Lee Moor. The latter visit gave members an impression of the rheology of suspensions on a large scale, and of the problems of conducting a nationally important industry in an ecologically sensitive area.

The Conference dinner was held in pleasant surroundings at the Moorland Links Hotel. The new President, Dr. Jones, presented the first of the society's Annual Awards to Dr. Wharlow. The grounds on which this award may be given are broad and various, but in the case of Dr. Wharlow most of them would be relevant, particularly his services to the British Society of Rheology and in the teaching of Rheology.

Altogether it was a satisfying conference. Your reporter had not attended an annual meeting for some years and was pleased to find the society still vigorous and flourishing. Perhaps it is a little more sober (I remember some riotous occasions 10-15 years ago!) but it is still informal and friendly and continues to attract members and participants from overseas.

E. B. ATKINSON

RHEOLOGICAL NOMENCLATURE IN FRANCE

Groupe Française de Rhéologie have produced further definitions for their *Dictionnaire*, the first part of which was published in translation in *Rheologica Acta* (1975) 14, 1098-1109.

Literal translations are given below, together with what I believe to be the English language equivalents. In some cases I have not been able to find an equivalent term with precisely the same meaning, and in others the English equivalent is much less precisely defined. Help with *accommodation* will be particularly welcome.

Comments or corrections should be sent to J. D. Weber, Université de Metz, Faculté des Sciences, Ile du Saulcy, 57000 Metz, France; or D. W. Hadley, J. J. Thomson Physical Laboratory, Whiteknights, Reading, RG6 2QT.

1.39 *Accommodation* (accommodation? No usual equivalent)

In harmonic tests, or more generally in all tests where the forced variable is a periodic function of time, there is said to be *accommodation* if, after the passage of a time t , the variations of the unforced variable y tend to become periodic, with the same period as those of the forced variable x . The coordinates x , y describe, in the limit, a closed cycle whose area is to a good approximation a measure of the energy dissipated in the course of a period.

1.43 *Restitution de forme* (shape recovery)

An operation in which the strain tensor is restored to zero. When the strain is homogeneous and continuous the body will recover its initial shape and dimensions. After an operation of *restitution de forme* the phenomenon of *effacement* is generally observed. Total *effacement* characterises the behaviour of a viscoelastic material.

1.44 *Effacement* (stress recovery)

After an operation of *restitution de forme* the decrease in the (Euclidean) norm of the difference between the actual stress and the stress existing prior to any deformation. If, at the end of a sufficiently long time, this difference becomes and remains zero the recovery is said to be total. If the difference remain non-zero, no matter how long the duration of the observation, the recovery is said to be partial.

Comment: *effacement* is the dual phenomenon of *recouvrance* (*recouvrance* should be translated as "strain recovery", rather than simply "recovery", as had been suggested earlier. DWH)

2.1 *Rhéologie* (rheology)

The science concerned with the relations between the stresses and the strains acting on a volume element, including, should it be necessary, their history and the actual values of their time derivatives.

2.9 *Fluide strict* (pure fluid?)

For an equilibrium configuration, that is to say one in which the stresses are not changing, a body is said to be a *fluide strict* if from that configuration all transformations that are geometrically isochoric, isothermal and sufficiently slow have an evanescent effect on the rheological properties including the equilibrium stress.

After a sufficiently long time the body will attain another equilibrium configuration, but in the same physical state that it had occupied in the initial configuration. Consequently: (1) if the behaviour is that of a *fluide strict* in an equilibrium configuration it is again so in all configurations of the same density at the same temperature. One can then speak of a *fluide strict* (at a given temperature and density) without specifying the configuration;

(2) a rotation being an isochoric transformation, a *fluide strict* is isotropic in all equilibrium configurations. In particular at equilibrium the state of stress is isotropic.

2.12 *Modele rhéologique* (rheological model)

An idealised system representative of rheological behaviour. The system is related to the exterior only through its two extremities, the relative displacements of which represent strain, and which are the points of application of collinear, equal and opposite forces that represent stress.

Electrical analogues are equally admissible for representing rheological models.

2.13 *Groupelement de models rhéologique* (combination of rheological models)

The formation of a rheological model from simpler rheological models, oriented in the same direction, with rigid connections between their extremities.

2.14 *Groupelement en serie* (series combination)

Rheological models are said to be formed into a series combination when they are joined end to end. The outside extremities are then the extremities of the combination. In such a combination the stress is constant from one component to another. The strain of the combination is the sum of the strains of the components. As a result the retardation function of the combination is the sum of the retardation functions of the components.

2.15 *Groupelement en parallele* (parallel combination)

Rheological models placed side by side are said to be combined in parallel when the extremities of each component on the equivalent side are rigidly joined together.

The extremities of the new model so formed are situated on the two rigid connections. The components and the combination express the same strain. The stress of the combination is the sum of the stresses in the components. As a result the relaxation function of the combination is the sum of those of the components.

2.16 *Modele de Kelvin-Voigt* (Kelvin-Voigt element)

A rheological model comprising a spring and a dashpot connected in parallel.

2.17 *Modele de Maxwell* (Maxwell element)

A rheological model comprising a spring and a dashpot connected in series.

2.18 *Modele de Bingham* (Bingham model)

A rheological model in which the following are connected in series: a spring; a parallel combination of a dashpot and a slider.

2.19 *Modele de Burgers* (Burgers model)

A rheological model comprising a Kelvin-Voigt element in series with a Maxwell element.

2.20 *Modele de Zener* (standard linear solid)

A rheological model comprising a spring in parallel with a Maxwell element (its behaviour is equivalent to that of the Poynting-Thomson model).

2.21 *Modele de Poynting-Thomson* (Poynting-Thomson model)

A rheological model comprising a spring in series with a Kelvin-Voigt element (its behaviour is equivalent to that of a standard linear solid).

5.1 *Comportement viscoélastique* (viscoelastic behaviour)

The rheological behaviour of a material which after a deformation followed by shape recovery will show complete stress recovery.

In the general case the response of a viscoelastic material comprises an instantaneous part and a delayed part.

Viscoelastic behaviour includes as limiting cases, at one extreme the purely elastic case, and at the other extreme the purely viscous case. In the purely elastic scheme only the instantaneous response is non-zero.

Viscoelastic behaviour is said to be linear or non-linear. In the one-dimensional linear case it can always be represented, completely, and as precisely as one wishes, by a rheological model composed exclusively of linear springs and newtonian dashpots.

5.2 *Viscoélasticité* (viscoelasticity)

The property of a material that displays viscoelastic behaviour.

6.7 *Ductilité* (ductility)

The aptitude of acquiring permanent deformation (plastic strain) under the influence of certain systems of loading. It may be characterised by the value of the plastic strain following fracture. It is a function of rate of deformation, pressure and temperature.

8.2 *Fissure* (crack)

In a solid the void between two closely neighbouring but non-adhering surfaces; that is to say incapable locally of transmitting stresses for which the normal component is a tension.

8.3 *Energie spécifique de rupture* (specific energy of fracture)

The energy expended in the neighbourhood of a crack front in the course of a controlled fracture, related to unit area of the newly created surfaces.

8.4 *Striction* (necking)

The transverse narrowing of a test piece subjected to a tensile experiment, produced (only) along part of the length of that test piece.

8.5 *Résilience de rupture* (impact resistance)

A mechanical characteristic defining the resistance to shock. It is equal to the ratio W/S of the work necessary to fracture the test piece by shock, to the initial surface area S of the right section where fracture occurred. The test must be performed under precisely defined conditions.

8.6 *Résilience de rebondissement* (rebound resilience)

A mechanical characteristic expressing the extent to which a body restores to the rigid moving body that has struck it the kinetic energy received. Most frequently employed in elastomer technology, it is then determined by the ratio of the height of rebound of the moving body to the height from which it was dropped. The test must be performed under precisely specified conditions.

8.7 *Rupture différée* (delayed fracture; fatigue)

Fracture produced in a specimen or a material some time after the application of a system of loads whose amplitude is less than that causing instantaneous fracture.

8.8 *Endommagement* (damage)

Progressive diminution of strength.

8.9 *Fatigue* (fatigue)

Damage caused by the repetition of mechanical forces, and which can result in delayed fracture. When fracture occurs after a small number of cycles (e.g. $< 10^4$) the fatigue is said to be oligocyclic. By extension the phenomenon of damage under constant stress is sometimes called static fatigue (*fatigue statique*). It is advised that this phenomenon be called *endommagement statique*.

8.10 *Essai de fatigue* (fatigue test)

A test in which a specimen is subjected to a system of loads which varies with time, either in a periodic or aleatory (random) manner. A periodic system defined by a parameter is said to be repetitive (*répétée*) when the parameter varies from 0 to S; it is said to be alternating (*alternée*) when it varies from $-S$ to $+S$; it is said to undulate (*ondulée*) when it varies from $(S_0 - S)$ to $(S_0 + S)$.

8.11 *Endurance* (endurance; lifetime (2))

(1) The quality of a material which is hardly sensitive (effectively insensitive) to fatigue; that is to say able to endure many cycles without damage, or possessing a fatigue limit approaching that of the instantaneous resistance.

(2) In a fatigue test with periodic loading the number of cycles N to fracture.

8.12 *Résistance à la fatigue pour N cycles* (resistance to fatigue for N cycles)

The value of the loading (determined statistically) for which the lifetime of the testpiece will be N cycles, the test being performed under conditions which must be specified precisely.

It is usually defined by the Wohler curve, which represents the load as a function of endurance N or its logarithm.

8.13 *Limite de la fatigue* (endurance limit)

The limiting value of the fatigue resistance for an unlimited number of cycles (in practice $N=10^7$ to 10^8 cycles). Below this threshold of stress there is no delayed fracture.

8.14 *Durée de vie* (lifetime)

In a fatigue test, or a static loading experiment, the time interval between the application of the load and delayed fracture.

8.15 *Resistance Pérenne* (static strength)

In a static loading experiment the limiting value of loading corresponding to an infinite lifetime.

8.16 *Ténacité* (tenacity, strength, fracture toughness)

The property of a material that possesses both a low aptitude for crack propagation and a high resistance to fracture.

The strength will be affected by (fait intervenir) cuts or pre-existing defects in the material, and a parameter characterises the matrix. For this last metallurgists use a coefficient, called K_{IC} , whose value varies according to the state of stress in the neighbourhood of the crack front.

CHARITIES AND POLITICAL ACTION¹

By J. D. Baxter, Department Law, UCW, Penglais, Aberystwyth

Submitted by W. M. Jones

The proposals which came before the A.G.M. of the British Society of Rheology concerning the implementation of the Helsinki agreement raise a question of law which flows from the Society's status as a charity. Because of this special status it is not possible to view the actions of the Society in the same light as action which might be taken by an individual or a group of individuals.

Although an individual is entitled to decide who he will have dealings with (subject to the rules relating to racial and sexual discrimination) a charity has to bear in mind the charitable trust imposed upon it, as well as the law which requires that the furtherance of the charitable object must be consistent with the law's definition of "charitable purposes". A political object, e.g. such as seeking to change the law, has never been regarded as something which could be required by a charitable trust. The Charity Commissioners published some guidance on this matter in 1969 and concluded that "... it is very unlikely that it would lie within any charity's purposes and powers to sponsor action groups or bring pressure to bear on the government to adopt or alter a particular line of action." It therefore follows that even where it is thought that a constitution of a charity might permit a particular course of action, if that action is construed as political action, it cannot be reconciled with the overall charitable purposes of the organisation. If the pressure is brought to bear upon a foreign government then there is no difference in principle since all that is being done is to broaden the scope of the political action and there are examples of organisations which

sought to achieve international peace and understanding being regarded as non-charitable.

The British Society of Rheology falls into that category of charity normally described as trusts for the advancement of science. Such trusts sometimes confer special incidental benefits on their members such as giving a degree of professional protection so that there have been cases where such bodies have acted in a way similar to professional bodies. Since there is no such function established by the Society's constitution there is no possibility of claiming that the motions referred to earlier are an attempt to protect the interests of foreign members. Alternatively it might be argued that in seeking to achieve implementation of the Helsinki Agreement the Society would be involved in the indirect "advancement of science" by seeking a more liberal regime in the U.S.S.R. which would encourage a free exchange of ideas etc. This argument has been put forward by educational trusts when attempting to justify political action and the Charity Commissioners stated in their 1969 report that "... if a charity with general objects . . . issues literature urging the government to take a particular course or organise sympathisers to apply pressure for that purpose to their elected representatives we think it is clear that the boundary has been overstepped."³

The problem for any charity seeking to enter an area where there is a potential political aim is that in the first instance it is for the Charity Commissioners to either refuse charitable status or to warn existing charities that they have entered the political arena. Should a charity not agree with the Commissioners' attitude then the only course of action is to apply to the Courts. This means however that charities are faced with the choice of accepting the Commissioners' views or risking the expense of litigation. In most cases it is not feasible to challenge the Commissioners' decisions and therefore their policy on political activity cannot be ignored.

The consequences which would flow from entry into the political arena would depend on the extent of the activity. If it were simply a matter of the Charity expressing a political view without incurring any expenses then, even here, there would have been a breach of trust which by itself would amount to improper conduct on the part of the trustees. If funds were spent in furthering the political view then such expenditure would have to be recouped by those responsible. The Charity Commissioners note in their report that such activities are unlikely to result in the loss of charitable status but point out that such activities could do harm to the status of charitable trusts generally.⁴ Where publicity is attracted it is quite likely that the Commissioners would take the matter up with the trustees concerned.

In the light of these various considerations the conclusion must be drawn that for the Society to proceed with the motion would be contrary to its charitable objects. Although political action of this kind on an isolated occasion may not attract the attention of the Charity Commissioners if no moneys were expended this does not alter the position that the charity would be pursuing a political cause. There are several methods which might be adopted to secure the same objective without contravening the Charity Commissioners' directions. The most realistic methods are:

(i) Individual members of the Society should form a separate non-charitable political trust, funded by separate subscriptions so that a new organisation comes into existence; or

(ii) Individual members should join with other scientists from other learned societies to establish an independent political trust campaigning for Human Rights for scientists generally.

It follows from what has been said above that it would be improper for the Society to terminate the membership of any member who comes from a foreign state pursuing policies which are disapproved of by the Society.

FOOTNOTES

1. What follows is a summary of an opinion submitted to officers of the Society during December 1978.
2. Report of the Charity Commissioners 1969 (H.C. Papers Session 69/70), page 6, paragraph 10.
3. See above, page 6, paragraph 11.
4. See above, page 6, paragraph 16.

Editorial Comment

My sentiments and the sentiments of the members attending the last A.G.M. can best be expressed by the editorial eloquently written by V. G. Harrison in the Bulletin of 1952.

"It is also my earnest hope that this Society will help keep alive that spirit of free and impartial enquiry, with open publication and discussion of results, to which the science of the past has owed its spectacular success. That freedom was won slowly and painfully, at the cost of men's lives; and it is to-day again menaced from two sides. On one side it is being fettered in the name of National Security. In the present deplorable state of the world, these chains may be unavoidable, but I am persuaded that in the long run they are thoroughly bad. Science has changed much since the days of Davy and Faraday and the change is, one fears, not for the better. On the other side we have the menace of political, racial and religious intolerance. From this we are never free. We had it in the middle ages over Galileo. We had it in the disgusting religious persecutions

in this country during and after the Reformation. We had it in mild form in the Nineteenth Century battle over evolution. We had it in more terrifying guise in Nazi Germany—and unhappily present day examples are by no means hard to find. Of this we can be assured—that no “world-view” is, or is ever likely to be, uniquely, finally and absolutely correct; and the day when science is made subservient to any code of political or religious dogma whatsoever, that day sees signed the death warrant of science as we knew it.”

LETTERS TO THE EDITOR

Dear Sir,

We fear that, in his contribution under “Scientific Enquiry” of the latest Bulletin (Vol. 21, No. 3), Dr. Cheng might not have fully grasped the tensor analysis he recommends his readers should study.

The trouble is that the stress (a second-rank tensor) would be related to a strain rate (another second-rank tensor) by a fourth-rank tensor of anisotropic viscosity, assuming a linear and instantaneous constitutive law for the material (i.e. no memory beyond that of the anisotropy and no non-linearity). Now in general a fourth-rate tensor has 81 independent components, but taking into account the symmetry and a zero trace (for an incompressible material) of the stress and the strain rate tensors and also an Onsager symmetry, there are really only 15 independent components. By decomposing a general strain rate into five components on five suitable “principal” strain rate tensors it is possible to represent the viscosity by 5 independent coefficients which multiply the five components of shear rate to generate a result for the stress (10 pieces of information are needed to specify the 5 principal shear rates). Thus viscosity in an anisotropic material is described by 5 coefficients associated with 5 principal tensors, and not 3 coefficients associated with 3 principal vectors as suggested by Dr. Cheng. An example which requires all 5 coefficients is a dilute suspension of rigid ellipsoids (Batchelor 1970, *J. Fluid Mech.* 41 545). If the further information is available that the anisotropy has an axial symmetry, then 3 independent coefficients will suffice.

We tentatively suggest that the term viscosity be used in an anisotropic material for the coefficient of the energy dissipation. This single scalar would of course depend on the relative orientation of the strain rate to the anisotropy.

Yours sincerely,

E. J. HINCH AND J. M. RALLISON

Department of Applied Mathematics and Theoretical Physics,
University of Cambridge.

Dear Sir,

I refer to the contribution from Drs. Hinch and Rallison to the discussion of the viscosity of anisotropic fluids. I would like to assure your non-mathematical readers that there is no real disagreement between Drs. Hinch and Rallison and my contribution published in B.S.R. Bulletin, Vol. 21, No. 3. There is, however, a difference in the depth of cover of the subject.

Drs. Hinch and Rallison have in mind a full and rigorous treatment, whereas I have taken only a step or two along the road that Drs. Hinch and Rallison have gone. Your readers will readily appreciate, from the contribution of Drs. Hinch and Rallison, why I have refrained from taking further steps in my contribution into the tensoral aspects of anisotropic viscosity. But, in view of the contribution of Drs. Hinch and Rallison, it would perhaps be useful to expand the discussion somewhat.

Another difference between the two contributions could be in the use of the term "viscosity". It is worthwhile to elaborate on this point because it reflects on our understanding of rheological relationships.

Although the original scientific enquiry was about viscosity, what we are really discussing is the relationships between stresses and strain-rates that act on an element of a fluid. The first steps that I have taken in my contribution follow the traditional lines; they lead to the concept of what I termed "principal" viscosities for an anisotropic fluid. What I did not mention is the possibility of the existence of normal stresses when an element is sheared in the way described. When Reiner first discussed normal stresses in 1945, he used the term "cross-viscosity", but now-a-days it is the usual practice to talk about normal-stress coefficients (which are the ratios of normal-stress differences to squared shear rate). It would appear, therefore, that subconsciously we make a distinction between stresses that are in the same direction as the strain-rate and those that are not. In relating a stress and strain-rate in the same direction, we talk about viscosity; but if a stress and strain-rate are not in the same direction, a different name is given to the coefficient relating them. (Other examples of this practice are elongation viscosity and Poisson's ratio which can be used to relate lateral strain-rates to tensile stresses.) And to confuse matters, we also use the term viscosity as a shorthand for shear viscosity. With these conventions in mind, a person would not automatically associate the term viscosity with the other coefficients, whether viscosities in themselves or cross-viscosities. But he would know, of course, that the rheological property of a fluid is not fully defined until all viscosities and cross-viscosities are specified.

As Drs. Hinch and Rallison remind us, there are in general 9 stress components and 9 strain-rate components, and it requires in

general 81 coefficients to relate them one to the other, if the behaviour is linear. Simplifications are possible under specific conditions to reduce the 81 to 15 and then to 5 independent coefficients. In the terminology of the preceding paragraph, some of these coefficients can be taken to be viscosities and the others cross-viscosities. But for simplicity one might call them all viscosities.

Drs. Hinch and Rallison suggest a new definition for "viscosity" as the coefficient of the energy dissipation. But, because of the reason that they stated, namely that this quantity would depend on the direction of the strain rate relative to the anisotropy, such a definition would not be suitable as a measure of material property, which should be invariant with respect to the methods and details of measurement.

I can follow Drs. Hinch and Rallison when they talk about stress and strain-rate tensors and anisotropic viscosity being a fourth-rank tensor. But, I must confess that they lose me when they move on to describe the "general strain rate" and its decomposition in terms of five "principal" strain-rate tensors. Maybe they would care to enlighten me, and other interested but non-mathematical readers, with a physical picture of what these categories of strain rates are? What are the 10 pieces of information needed to specify the five principal strain-rate tensors and how can one measure the five coefficients experimentally?

There is another property of anisotropic fluids which Drs. Hinch and Rallison did not mention. It was touched on by Batchelor (1970) and given a fuller treatment by Duffy (1978; *J. non-Newtonian Fluids Mech.*, 4, 177-193). This is that an anisotropic fluid can show time-dependent behaviour under simple shear, so that the viscosity (defined as the shear stress to shear rate ratio) as well as the normal stresses increase with time. It is interesting to note that this behaviour is predicted by Duffy from purely mathematical considerations without recourse to concepts of molecular kinetics.

Yours faithfully,

D. C-H. CHENG

Warren Spring Laboratory,
Stevenage,
Herts.

Dear Sir,

Unfortunately I am now nearly blind and for this reason, combined with my age, I am giving up my Editorship of *Biorheology*. But someone has read to me the very interesting *Bulletin*, Vol. 21, No. 3 of the B.S.R.

I gather that you would like to have some news on the probable distribution of interest in the near future in the field of Biorheology and medicine.

Of course Biorheology covers a very wide field, indeed there is a great deal going on concerning mucus, synovial cervical and bronchial. There is also much work on the rheological properties of bones and skin and occasional rather unlikely subjects such as the flow of sap in plants.

But I think that by far the widest field of research for some time to come will remain with blood and blood vessels—problems of flow of blood in the vessels, coagulation and blood pressure, all these in connection with various diseases. The viscosity of blood also varies considerably under various pathological conditions. There is also a wide field of research concerning collagen.

If I can be of any further help with questions concerning Biorheology please be sure to let me know.

Sincerely yours,

G. W. SCOTT BLAIR

ANNUAL AWARD—NOMINATIONS

The first Annual Award of the British Society of Rheology was presented to Mr. R. W. Whorlow.

Nominations for this year's award should be sent to the secretary as soon as possible.

REPORT ON VISCOMETRY FROM WARREN SPRING LABORATORY

A comparison of 14 commercial viscometers and a home-made instrument. D. C-H. Cheng, W.S.L. Research Report No. LR 282 (M.H.), 1978, 137pp., £15.00.

SUMMARY. The aim of this report is to demonstrate the real importance of instrument calibration and correction for a variety of instrumental effects in high precision viscosity determination. A master batch of a 3% carboxymethyl cellulose solution was used on 15 viscometers of the types: coaxial cylinder, single cylinder, cone-and-plate, parallel plate, tube, filling tube, U-tube, falling sphere and rotating disc, by a group of 25 experimenters. Instrument calibrations were carried out for torque or pressure, speed or flow rate and measuring element dimensions. Instrumental errors were considered and corrections made wherever possible: on gap-setting error, end and/or edge effect (including proximity of container

wall), wall-slip effect and shear rate or shear stress variation due to non-Newtonian behaviour. The importance of monitoring test temperature was demonstrated. The results obtained from the different types and models of the viscometer, covering the range approximately 0.1 to 10^5 s^{-1} , were compared and the relevance of instrument calibration and instrumental errors discussed. In addition to providing data for appraising their effects on the accuracy of viscosity measurement and on repeatability for individual experimenter, and reproducibility between experimenters and instruments, this report gives details of data treatment and examples of tabular layout to assist the viscometer user.

Copies of the above report may be purchased from the Laboratory, P.O. Box 20, Stevenage, Herts. Please send payment with your order.

Staff Vacancies

CRANFIELD INSTITUTE OF TECHNOLOGY DEPARTMENT OF MATERIALS POLYMER RESEARCH

The Department has the following vacancies:

- (a) Project Leader
- (b) Research Officers
- (c) Research Assistants

The successful applicants will work on a variety of problems related to the fabrication and properties of engineering plastics, in close co-operation with sponsoring industrial organisations. Applicants for posts (a) and (b) should have R & D experience in physics, mechanical engineering, polymer/materials technology, or related subjects. Research assistants need no such experience and will have the opportunity to work for a higher degree.

Salaries will be in the range (currently under revision) £3,189 to £6,900 according to age and experience. Superannuation on U.S.S.

For further information contact

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APPLICATIONS FOR MEMBERSHIP—DECEMBER 1978

- | | |
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London, N.W.3.

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Instron Ltd.,
Coronation Road,
High Wycombe.

Unilever Research Ltd.,
Colworth House,
Sharnbrook, Beds.

OBITUARIES

HENRI CHARLES WEISS (1893-1978)

Henri Charles Weiss, the principal founder of **Groupe Français de Rhéologie**, died after a long illness on 9th April, 1978, ten days before his 85th birthday. He was born in Paris, to which his father had moved following the German annexation of Alsace, and graduated from **l'Ecole Supérieure d'Electricité** in 1916. In 1923-24, following submission of a thesis on diffusion in metals, he spent a year in Britain as a Ramsey Memorial Fellow, studying the use of x-rays for the examination of alloys.

In 1925 he joined the recently established **Ecole Supérieure du Pétrole** at Strasbourg, and eventually became its Director. Simultaneously he held a chair at Strasbourg University. From 1953-67 he was a scientific councillor in **l'Office National des Universités**.

His work concerned the general application of physial chemistry to the properties of petroleum products, and he came to rheology through studies of the viscosity of lubricating oils and drilling muds. He displayed an equal interest in literature and the arts.

When attending the Second International Congress of Rheology at Oxford in 1953 he realised the extent to which his country lagged behind others in providing a meeting place for those with interests in the many different aspects of rheology, and on his return to Paris persuaded the Director of C.N.R.S. to establish a National Commission of Rheology. In February 1954 the **Groupe Français d'Etudes de Rhéologie** held its first meeting, and shortly afterwards followed the thrice-yearly **Cahiers**, funded by C.N.R.S. In 1960 H. C. Weiss was the joint organiser of a C.N.R.S. conference on Non-linear Rheology, which was attended by a number of visitors from outside France.

He was a modest man, scorning honours and beavering away behind the scenes. His discreet charm and his humour masked a person of great culture and deep humanity.

[Condensed from **Cahiers G.F.R.**, 1978, **5**, 1-3. The tribute was written by his colleagues of long standing in G.F.R., Pierre Thirion and Bernard Persoz.]

G.F.R. suffered a further loss in 1978 by the death at the age of 75 of Th. Vogel, Director of the C.N.R.S. Physics Research Laboratories at Marseille from 1958 to 1973. Though he was a mathematical physicist it was at his initiative that an experimental rheology unit was established at Marseille. He had been a member of G.F.R. for many years.

DIARY

1979

April 2-5. "Deformation, Yield and Fracture in Polymers." Cambridge.

April 18-20. "Rheology of Associating, Structured and Biological Systems." Amsterdam.

May 28-30. First National Conference of Australian Branch, Monash University, Melbourne, Australia.

September 11-14. "Applied Rheology." Aberystwyth.