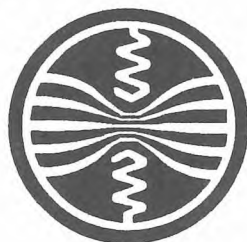


THE BRITISH SOCIETY OF RHEOLOGY

BULLETIN



1991, Vol. 34 No 1

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1990/91

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EDITORIAL

I would like to apologise for the late distribution of the last issue of the Bulletin. This was caused by some problems with the software on which members' records are held. I am sorry that this meant that information on some meetings reached members too late for them to be able to attend.

The Council has agreed to two new initiatives, briefly mentioned in the Commentary in this issue. One is to establish a working group to look at the feasibility of producing a Handbook of Rheological Terms. This would be something of an encyclopedia, with entries describing and explaining the background to terms in common use in rheology. Its scope would fall between that of a dictionary or glossary and that of a review article in a learned journal. The other is to establish a working group to consider the question of whether there should be more openness on the part of manufacturers of instruments about the computer software employed in the conversion of raw measurements to rheological parameters. I am sure that members of the Society will have views on both these topics, so please contact David Cheng, the President, who is convening the groups.

Finally I would like to draw attention to the supplement to the catalogue of the Scott Blair Collection which appears in the centre of this issue, and to the notices about the Annual General Meeting and the Autumn Meeting of the Society, to be held in Bristol. The latter has been reduced in scope from that announced earlier, partly to reduce costs.

COPY DATE FOR NEXT ISSUE: June 15th



THE RHEOLOGY OF SURFACE COATINGS

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INTRODUCTION

There are many different types of surface coatings and they are applied on to many different types of substrate. These different surface coatings include: paint for decorative and industrial use; printing inks for use on paper, tin cans, food packaging etc; enamels and lacquers for coating tin cans; clay/latex slurries for paper coating; materials for use on photographic film; UV curable inks for coating printed circuit boards; and primers and rust preventives for use in the automotive industry. During preparation, transportation, storage, application and curing surface coatings are subjected to a wide range of strains, stresses and strain rates. Figure 1 illustrates the range of shear-rates of interest for a typical (colloidal) coating system. As a result, designing these materials to give acceptable rheological behaviour under any (or all) of these given deformations is an extremely complex problem. Historically it has been part of the remit of the formulation chemists to use their experience to develop a product with the correct rheological characteristics. In the main this involves the use of qualitative, subjective tests which require a fairly experienced 'eye'. Also many of the quantitative tests used are not appropriate, as they are being used to test materials for which they were not designed. Examples of this include the use of Ford cups or Laray viscometers to test *non*-Newtonian materials (eg. white enamels or printing inks). However, the new generation of rheological instrumentation should enable the skills of the formulation chemist and the rheologist to be combined in order to aid product development.

This article aims to highlight the complex rheological requirements of a coating system and the way in which modern rheometers may be utilised to develop systems to meet these requirements.

THE RHEOLOGICAL HISTORY OF A SURFACE COATING

Figure 1 illustrates quite clearly that a surface coating accumulates a considerable amount of rheological history from the preparation to the curing stage. Furthermore it must be realised that this diagram is probably far from complete. Two important omissions from this scheme are that it does not recognise the fact that (a) some of the processes indicated are *stress* controlled as distinct from *shear rate* controlled, and (b) surface coatings exhibit viscoelastic behaviour.

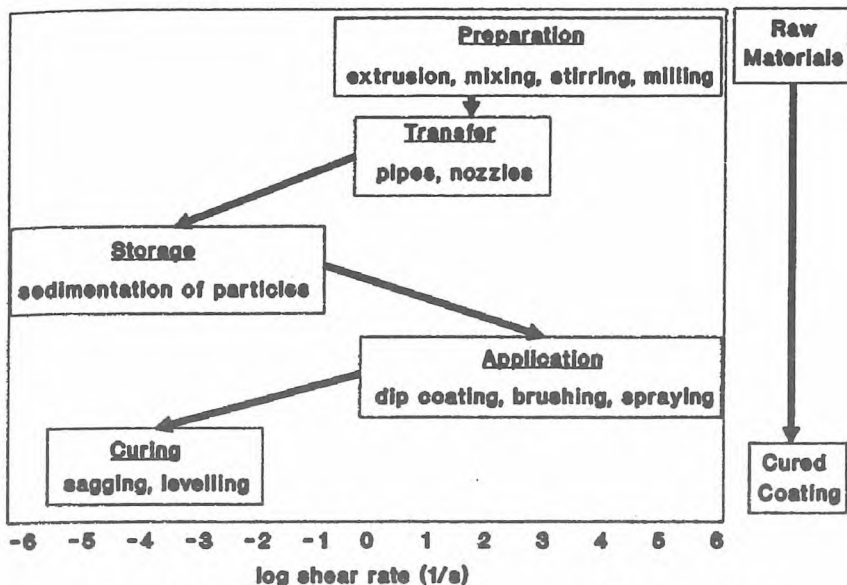


Figure 1 Illustration of Shear rates encountered during coating

(a) PREPARATION

During this stage the material may be subjected to one or more of a number of processes some of which are listed in figure 1. The process of preparing a coatings system by extrusion may be illustrated by considering the manufacture of, for example, electrographic toners used in the photocopying industry. These systems are prepared by combining a polymer resin with the pigment (for example, carbon black) at a fusing temperature above that of the resin. The shear rates encountered in this process are fairly moderate with a maximum of about 500 s^{-1} . Problems may arise during the process since the concentration of the resin relative to the pigment is high and therefore its molecular weight, and its molecular weight distribution, will have a large influence on its flow behaviour. As a further example consider the pigments used in the preparation of surface coatings which are supplied in dry powder form. The surface charges on the pigment particles result in the formation of aggregates. The use of high speed mixing and/or milling serves two purposes: firstly, the pigment particle aggregates will be broken down; and secondly the particle surfaces will be exposed to the wetting agents in the dispersing medium necessary to form a stable (or weakly flocculated) dispersion. These processes will be carried out at fairly high shear rates ($10^3 - 10^6 \text{ s}^{-1}$) and considerable problems may be encountered due to the high loading, and small particle size, of the pigment particles.

(b) TRANSFER

Once the surface coating has been formulated it will be transferred from the preparation vessel into cans, storage vats or transport tankers. This will probably involve the material being pumped via a pipe line. The rheological behaviour of interest here includes the force required to initiate the flow of the material, and the subsequent force required to maintain a reasonable flow rate. However since these coating systems are likely to contain a high (volume) percent of pigment particles they will be highly structured. Therefore the force required to initiate the flow may be very high; but once the material starts to flow it will thin rapidly under shear which may result in very high flow rates in the pipe line. The high flow rates generated may further lead to dilatancy (or shear thickening), which is disastrous in production terms. This illustrates the close control needed to achieve the correct rheological behaviour.

(c) STORAGE

Since many surface coatings are two phase systems, that is, solid particles dispersed in a liquid medium, sedimentation may be a problem. Surface coatings are usually designed to be weakly flocculated structures, although the use of thixotropes and associative thickeners in the dispersion medium to induce structure are finding more widespread use. This means that on storage the material will form a network of particles, and it is desirable that this network has the same volume as the total volume of the sample so that there will be no supernatant liquid visible which is aesthetically displeasing to the customer's eye. This weakly flocculated material is readily redispersed by the minimum input of energy. The strength of this weakly flocculated network may be measured using a controlled stress instrument and hence the stability predicted. Furthermore this inherent strength will be relevant during transportation, as this may cause the structure to partially break down and the discrete flocs to sediment rapidly.

(d) APPLICATION

The type of application process for the surface coating will have a strong influence on its desired rheological properties. For example, if a system is to be applied by brush it is necessary for the material to have a viscosity low enough to penetrate the bristles of the brush. This will not be a consideration for a sprayed system, although the material must have a viscosity low enough for initial start up of the spray gun not to be a problem. As indicated in figure 1 the shear rates of interest vary enormously depending on the process, and this will have an influence on the desired rheological properties of the material prior to and immediately after the application process.

(e) CURING

This has been taken to refer to phenomena such as flow-out of brush marks, sagging and levelling, and also the change in rheological properties due to UV or thermal curing. An important factor in the change in rheological characteristics of coatings systems is the loss of solvent during the curing stage. This is quite difficult to mimic, although one solution is to measure the rheological behaviour of the system at different solids concentration. The process of flow-out will have a major effect on the final appearance of the surface coating. For example, in a paint system the flow of the material after application due to gravitational stresses and stresses generated by surface tension gradients will determine the 'smoothness' of the dried film. Similarly these forces will affect the dot gain (or printing quality) of printing inks. The phenomenon of sagging is extremely important when coatings have been used on surfaces which may, at some stage during curing, be vertical. Using modern rheometers it is possible to probe the relevant rheological behaviour.

As can be seen the rheological requirements of any surface coatings system are very complex. However, in order to be fully confident that any given system exhibits the correct rheological behaviour it is necessary to characterise the material as fully as possible. It is appropriate at this point to recognise that most (if not all) coatings systems will exhibit viscoelastic behaviour during application. The consequences of this behaviour will be highlighted in the following section.

VISCOELASTIC BEHAVIOUR OF SURFACE COATINGS

Since surface coatings are viscoelastic it is important that the coatings technologist is familiar with the various deformations and forces (or stresses) which will act upon the material during processing and application. The magnitude and time scale of these disturbances will dictate the observed rheological behaviour. The parameter which defines this behaviour is the Deborah number, D_e ,

$$D_e = t_r / t_e$$

where t_r is a characteristic time of the material and reflects the time taken for imposed deformations to relax, and t_e is a characteristic time of any experiment. The behaviour exhibited by materials is illustrated by the magnitude of the Deborah number, i.e.

$D_e \gg 1$ solid-like behaviour

$D_e \ll 1$ fluid-like behaviour

$D_e \sim 1$ viscoelastic behaviour

Materials of interest in the surface coatings industry will have relaxation times of the order of 10^{-4} to 10^4 s. Therefore consider a system

with a characteristic time, t_r , of about 1 second. If this material is applied using a spray gun, where the shear rates generated are about 10^5 s^{-1} , then the time scale for the "experiment", t_e , is 10^{-5} s . Therefore the Deborah number would be about 10^5 , and the material would behave as if it were a solid (with potentially disastrous results!). On the other hand, after spraying the material will be allowed to "flow-out" under gravitational and surface tension forces. The shear rates generated here will be in the region of 10^{-4} s^{-1} . Thus the Deborah number will be 10^{-4} and the fluid-like behaviour of the material would dominate. Of course this response will be time dependent due to solvent loss, or thermal or radiation curing. Also the overall behaviour of the systems will not be dependent on a single characteristic relaxation time but a spectrum of times which reflects the numerous relaxation processes occurring in the material.

It is important to consider the measurement of the *linear* viscoelastic behaviour of materials. The condition of linear viscoelastic behaviour is that the response of a material (e.g. strain) is linear with respect to the input signal (e.g. stress). Also the coefficients of the time differentials are constant. There are a number of reasons for performing experiments in the linear viscoelastic region.

Firstly, it is often the aim of the rheologist to use the measurement of bulk rheological parameters to obtain information on the microstructural properties of the material. This relationship will be easier to determine if the rheological measurements were obtained in the linear viscoelastic region. Secondly, the knowledge gained in performing linear experiments, both theoretical and practical, will help in interpreting data obtained when working in the non-linear region. Thirdly, some of the rheological behaviour observed in the linear region will be relevant to the actual performance of the material.

The viscoelastic response of coating systems may be investigated using modern rheological instrumentation. These instruments, and their utilisation, are described in the next section. Only the more commonly used rotational type rheometers will be considered.

RHEOMETERS AND RHEOLOGICAL CHARACTERISATION

The ability to utilise quantitative techniques to characterise the rheological behaviour of materials has been greatly enhanced in recent years. The combined flexibility and sensitivity of rheological instrumentation has increased by orders of magnitude over earlier viscometers/rheometers. This innovation has been influenced by two major factors:

- (a) The development of laboratory personal computers has given access to flexible experimental design and rapid data acquisition; and
- (b) advances in precision engineering have increased the sensitivity and stability of modern rheometers.

These rheometers allow experiments to be performed on materials which are stress, strain or strain rate controlled. Furthermore, it is possible to perform both static and dynamic tests using the same instrument. It is also pertinent to add that a very wide temperature range can be covered by these instruments (about -100°C to 400°C). Given all of these factors the rheological behaviour of any material under virtually any circumstances should be accessible.

These rheometers represent a substantial investment for any industry. As a result there is a feeling that the instruments are only for use in a research environment. It is suggested that the rheometers are used in the development stages of any given formulation, so that the material "has the right rheology". Then this information is used to correlate with data obtained from Ford cups or Laray viscometers. However the use of rheometers, operated by qualified/trained personnel, should become more widespread, and could be used as a *quality assurance* tool. In this way avoiding one performance disaster caused by inappropriate rheological behaviour would repay the investment in the equipment!

The fundamental question to be asked before performing a rheological test is what information is required from it? The flexibility of modern rheometers allows complicated application processes to be closely simulated by the careful design of similarly complicated test procedures.

Consider for example the curtain coating of a horizontal, fast moving substrate by a material stored in a reservoir. A schematic for the process is shown in figure 2. The diagram illustrates the rheological behaviour of

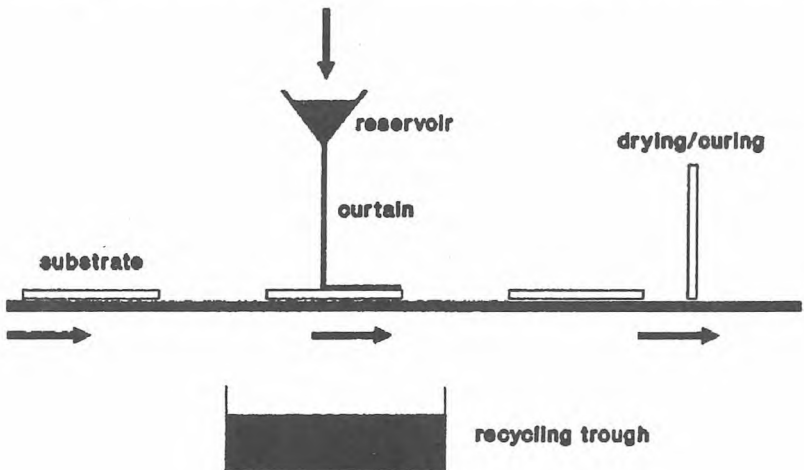


Figure 2 Schematic diagram of a curtain coating process

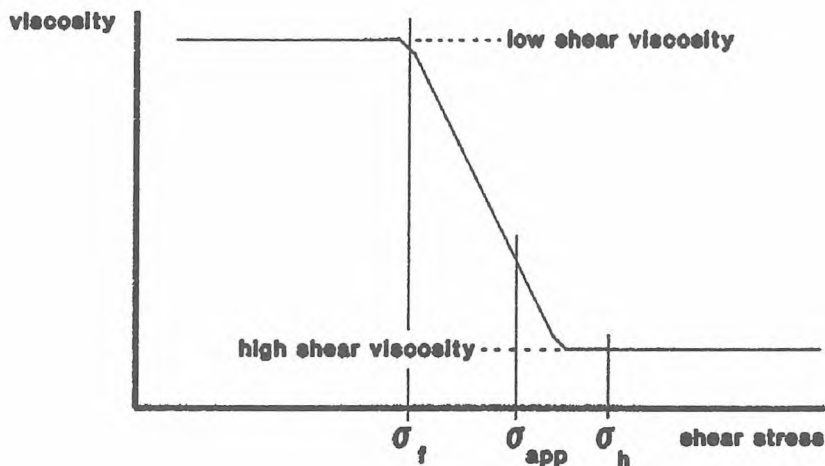


Figure 3 Viscosity profile of a shear-thinning material

interest in this simple representation. The coating material will be pumped from the reservoir through a long slit to form the curtain. The rheological behaviour of interest here is concerned with the effect of the applied force, F (or stress, σ) on the flow behaviour of the material. Therefore it would be necessary to perform a stress viscometry test on the material, which would result in a curve such as that represented in figure 3. The minimum stress required to force the material to flow out of the reservoir at an acceptable rate is σ_f . Above σ_f the material will rapidly shear thin and adequate flow would result. Consider that the surface coating is forced out of the reservoir using an applied stress of σ_{app} . As the time of application of the stress increases the material will further shear thin. Therefore, in order to maintain a constant flow rate of material to keep the coating thickness constant, the stress will have to be decreased until equilibrium flow is achieved. If a force is chosen so that $\sigma_{app} > \sigma_h$ then the flow will be Newtonian and equilibrium flow will be almost instantaneous. As the substrate is moved through the curtain it will be coated with a thin film (about 30 microns) of material. At the speeds of operation the coating will be subjected to a shear rate in excess of 10^4 s^{-1} and the viscosity at this shear-rate will be important.

While still horizontal the coating will flow out and level, which will be important if the substrate is an uneven surface. The stresses acting on the material will be those generated by surface tension gradients. The

viscosity of the coating at these stresses will determine the smoothness of the final coating. This may be probed by performing a constant frequency stress-controlled oscillation experiment to measure the relative magnitudes of the storage modulus (G^1), which will be related to structure re-build in the material, and the loss modulus ($G^{11} = \eta^1/\omega$), which will be related to the flow properties of the material, both as a function of time. If the substrate is then held vertical before curing the coating will be subjected to gravitational stresses. Again a constant frequency stress-controlled oscillation experiment should be performed on the coating, but using a stress which equates with that generated by gravity.

Overall this represents a reasonably complicated set of test procedures. However with some rheometers it is possible to perform all of these experiments, with built-in time (and temperature) programmes, consecutively. Although the design of the total test procedure will be time consuming, it could then be 'stored' for future use in quality control/assurance laboratories. With experience it will be possible to produce templates for acceptable rheological behaviour during any part of the test.

CONCLUSION

This article has attempted to review developments in rheological instrumentation for use in the coatings industry citing specific examples to illustrate the value of developing methods for obtaining meaningful rheological data. However, this short article has not done full justice to the technology available to characterise surface coating materials rheologically. It is important that the industry takes advantage of available technology to enable it to compete with Japan and the United States. Furthermore rheological characterisation will play a major role in the development of more environmentally friendly water-borne and high-solids coatings. That argument alone justifies the investment to enable the industry to move forward.

THE EARLY YEARS OF THE SOCIETY (from the Archives)

Continuing the theme of this Golden Jubilee year, I reprint here a brief history of the Society which was prepared by Norman Wookey to mark the 21st Anniversary of the formation of the British Rheologists' Club. Norman was Hon. Secretary of the Society from 1955 to 1958 and we recently heard from him after about 25 years. He still does some consulting and is currently concerned with a viscosity problem. I can provide his address on request.

A NOTE ON THE FORMATION AND DEVELOPMENT OF THE BRITISH SOCIETY OF RHEOLOGY

Strange as it may seem it appears that the Society owes its origin in 1940 to a similarity between the rheology of printing inks and those of secretions from the uterine cervix of the cow. In an early issue of the Bulletin Dr Lang, the Secretary of the Institute of Physics, describes how he arranged for Dr Scott Blair and Dr Harrison, who were independently working on methods of measuring the properties of these materials, to meet and discuss common aspects of their work and this must be taken as the first meeting of the British Rheologists' Club. These meetings continued, and it was then thought that perhaps twenty or more people might be sufficiently interested to meet at lunch two or three times a year to discuss rheological problems, particularly those of wartime importance. A self-appointed committee of three used to meet in Scott Blair's drawing room at Reading, with help from two co-opted members: Mrs Scott Blair to provide encouragement and refreshments, and a dog called Wolfgang whose function is not entirely clear from the records (he sounds a very fierce animal and perhaps the early meetings required someone to keep order). It was decided that the Club should differ from other scientific societies in having no rules, no formalities, and a subscription of 5/- per year. It was of course later found that, contrary to early expectations, the Club was "shockingly successful" and, with a membership of some hundreds, a more formal organisation later became necessary.

A circular letter dated August 1940 was sent to scientists interested in problems of deformation and flow, and an Inaugural Meeting on "*Rheology in Industry*" was held on November 16th 1940 at the University of Reading, the first President being Sir Geoffrey Taylor F. R. S.. The first Bulletin was published in duplicated form in January 1941 and the first Register of Members containing 105 entries was issued in December.

A subject of considerable interest in the early years was the classification of rheological properties and a meeting on the subject was

held at Birmingham in January 1942. Two charts of rheological properties subsequently published in *Nature*, are still a useful guide to different types of rheological behaviour.

The first major conference organised by the Club was held at St. Hilda's College, Oxford, in July 1944 and the proceedings were published as the well-known *"Essays in Rheology"*. The book contains in its preface an interesting account of the early development of rheology, including the facts that the word "rheology" was first suggested by Professor Bingham and that the American Society of Rheology was formed in 1929 when Dr Scott Blair attended the first meeting of the new Society. Treloar's paper on "The Meaning and Use of Certain Rheological Terms" also clearly summarises the early ideas on the difficulties of rheological classification and nomenclature.

Late in 1944 the *Bulletin* became the printed booklet with abstracts which was to be standard for some years. However, as all good things have to be paid for the Club subscription had to be raised to £1 in September 1945, but by now rheology was obviously becoming a very respectable and lucrative profession and the only apparent effect was that the membership increased further.

Later the Society became even more respectable and published a full set of Rules which have been very useful in helping to preserve a continuity in the administration of the Society when changes in officers have occurred.

In 1948 all rheologists who had been unable to take holidays abroad during the war years were glad to hear of the hospitality of our Dutch friends who acted as hosts for the first International Congress on Rheology at Scheveningen, and a large British contingent spent a happy and instructive week at this meeting. The *Proceedings* of this Congress is still a useful reference book, and it also contains an interesting "Report on the Principles of Rheological Nomenclature" by Burgers and Scott Blair.

In 1950, after some heart-searching discussions amongst original Club members, it was decided to change the name of the Club to the British Society of Rheology. The main reason for this seems to have been the implications attached to the word "Club" by some senior industrialists who raised suspicious eyebrows when their staff wished to obtain a few days off to attend "Club" meetings, particularly when they often seemed to be held in women's colleges and to be on subjects which appeared so abstruse that they were obviously a cover for more pleasant activities. There was little substance in this suspicion as most of our Conferences were heavily loaded with lectures and discussions, although Dr Mardles did occasionally introduce a much appreciated lighter note with his arrangements for social evenings and visits.

In July 1953 the Second International Congress was held at Oxford and the international links with rheologists abroad were further strengthened in 1956 when on our suggestion all National Societies of Rheology agreed to regularly interchange journals and other information. An attempt to form an International Union of Rheology, affiliated to the I. C. S. U., was made at the Oxford meeting and although this was later abandoned the present more informal arrangement maintains adequate liaison between national groups of rheologists. A special arrangement exists with rheologists in Australia who are members of the British Society but are also organised in two flourishing groups holding their own meetings.

In May 1957 a very well attended Conference on the Rheology of Elastomers was held at Welwyn Garden City, and in honour of the many foreign guests the Society members donned their evening dress and held a formal dinner complete with speeches, so that a stranger would have thought the Faraday Society was meeting instead of the usually informal rheologists. About this time we also opened negotiations with Pergamon Press which later resulted in the publication of two volumes of *Proceedings of Conferences*, the first on "*Elastomers*" and the second on "*Disperse Systems*". both of which are very useful collections of authoritative papers on these two subjects. The introductory papers by Treloar and Oldroyd in these two books are models of clarity in presenting reviews of rheological knowledge.

Later arrangements were made for Pergamon Press to publish "*Rheology Abstracts*" on our behalf and this publication together with its annual index is a most useful addition to the scientific literature. The Bulletin continues to give news of interest to our members and includes items like the list of textbooks of rheology which is so valuable to newcomers in rheological work.

The 3rd International Congress was organised jointly by the two German Societies, and was held at Bad Oeynhausen. The opportunity was taken for members to establish contact with colleagues from many countries, including Russia, and to meet friends made at previous Congresses.

The finances of the Society have always been sound and each successive Treasurer has been careful to add his mite to the reserve during his term of office. Other learned Societies always seem to need to raise subscriptions continually and to appeal for more funds on frequent occasions, but in our Society we have always been a little embarrassed by the surplus wealth in the funds and one Committee discussed at length whether we could arrange a reduction in the subscription of £1. We eventually decided against it as we often have pure mathematicians as Treasurers and they prefer integers to fractions in their calculations. It is

perhaps likely that the use of their wives as unpaid, or at least cheap, labour in much of the clerical work of the Society has been a factor in allowing officers to keep subscriptions at their low level.

The Society is now an institution rather than an informal club but the meetings are no less pleasant, and the very considerable amount of voluntary work which has to be done is now spread over a larger number of officers. The welfare of small societies with no permanent staff depends very largely on the energy and ability of the officers, and the British Society of Rheology was fortunate in its early years in having officers who combined the keenest interest in rheological matters with unusual ability in committee work and administration. The Society has, perhaps because of its small size, always been a good place for making friends and it is unlikely that anyone who has given time and energy to the Society has not been amply repaid in the human contacts made in the course of the work. The Society has now been in existence for 21 years and it is hoped that future rheologists will obtain as much pleasure and help from the organisation provided by the Society as we have done in the past.

N. Wookey, 1961

EXTENSIONAL VISCOSITY DETERMINATION FOR THE TEST POLYMER SOLUTION A1

This meeting was held at the Hotel de Paris, Villard-de-Lans, France, January 21-24th, 1991. The weather was sunny, the snow was white and powdery and considerable experience was gained of down-hill and cross-country skiing. Altogether a most successful venue.

Professor Walters opened the meeting with a formal welcome. He then reminded delegates of the two previous similar meetings: first at Chamonix and then at Combloux. At Chamonix techniques and results were described but these did not refer to the same liquid so comparisons were invidious. Hence it was decided to work with a common Boger liquid (M. 1—prepared at Monash) but the results presented at Combloux by various workers were still scattered (outside experimental tolerance) (Ref. 1). Another attempt was therefore to be made to obtain significant agreement between workers to enable a firm number to be given for the elongational viscosity of a fluid under the specified conditions of the experiment. Fluid A1 was therefore prepared at Aberystwyth and tested at the various laboratories represented at this conference.

Fluid A1 is a 2% w/v solution of polyisobutylene (B200) in decalin. It had been used as a test fluid some years ago, under the guise of D1, when measurement of N_2 was being investigated. Steady shear and oscillatory shear experiments were done over a range of conditions and agreement between laboratories was good.

The remainder of the first session of the conference was devoted to the shear properties of A1.

SHEAR FLOW.

DR N. HUDSON (Strathclyde) reported experimental results of work with the Weissenberg (steady and oscillatory shear) and with the Carri-Med constant stress device. σ , η , N_1 , η^1 , G^1 were evaluated at various temperatures for several $\dot{\gamma}$ and ω . The material was shear thinning (fitted to a Cross model) with $\eta_0 \approx 20 \text{ Pa s}$ at 20°C . Retardation time on the constant stress $\approx 7\text{s}$. The results agreed well with those found for D1.

DR T. E. R. JONES (Plymouth) reported similar experiments and results. In addition, Couette flow in a double concentric cylinder had been investigated. The Carreau-Yashida model in shear flow was best in correlating results. The Plymouth results had been found to agree well with the Aberystwyth results. η^1 and G^1 were found to be independent of amplitude justifying a linear model. η^1 was found to diminish when the oscillatory flow was superposed on a steady flow.

MR PASCAL BAYLOCQ (Grenoble) reported on the results of his experiments done when he was seconded to Aberystwyth. As well as the apparatus used routinely as reported by others (above) the capillary viscometer (Rosand) had been used to extend data taken on the Weissenberg (at $\dot{\gamma} \rightarrow 10^3 \text{ s}^{-1}$) to $\dot{\gamma} = 10^6 \text{ s}^{-1}$. Values of η from the Weissenberg and the Rosand agreed at $\dot{\gamma} = 10^3 \text{ s}^{-1}$ but the slope of the line (log curve) between 10^3 and 10^6 s^{-1} was different from that between 1 to 10^3 s^{-1} . Also at a stress of around 120 Pa in the constant-stress apparatus a "stick-slip" regime occurred whose onset depended on the previous stressing of the fluid (an instability in the flow?). T. E. R. Jones said such an instability had not been found at Plymouth under similar conditions, nor elsewhere.

PROFESSOR P. CARREAU (Montreal) had applied the Weissenberg and Bohlin (a concentric cylinder rheometer). Again results were in general agreement with others. The Cox-Merz rule had correlated oscillatory data. The time constant of the fluid ranged from 10s to 0.1s, depending on frequency. G^1 diminished with deformation rate (from 20 Pa down on the Bohlin).

EXTENSIONAL FLOW

DR T. SHRIDHAR (Monash) described filament stretching experiments done with M1, whereby the falling lower plate (see Matta Ref. 1) had been developed to enable the rate of fall to be controlled to give a constant (adjustable) strain rate. The stress was determined by attaching the upper plate to a microbalance. To offset the gravity flow of fluid in the filament, some experiments had been done with the filament under water.

DR R. F. LUQUE (Shell, Rijswijk). A cotton bud cleaner dipped into fluid and withdrawn stretches the filament which becomes attached to it. The stress was measured by a microbalance, the rates of strain were determined from visual records using a high-speed camera.

DR E. COLLANSON (Rijswijk) detailed results obtained using Luque's apparatus. Extensional viscosity η_E was determined as a function of time of the experiment; values ranged from 600 Pa s down, at a strain rate $\dot{\epsilon}$ from 3 to 1 s^{-1} .

DR J. E. MATTA (Maryland) described the application of the freely falling plate to liquid A1. Apparent η_E was around 200 Pa s with $\dot{\epsilon} = 20 \text{ s}^{-1}$.

DR W. M. JONES (Aberystwyth) described results from the falling pendant drop experiment (see Jones, Hudson and Ferguson in Ref. 1) in which applied force (stress) was varied by changing the size of the pendant drop. Apparent η_E increased with strain rate and with strain. Values of η_E ranged from 300 Pa s to 14000 Pa s with $\dot{\epsilon}$ in the range 2.5 to 6 s^{-1} and ϵ in the range 0 to 16 .

PROFESSOR C. CHNIELEWSKI (Michigan) described a spin-line viscometer and its application to various materials. For A1 $\dot{\epsilon}$ decreased down the length of the fibre. $\eta_E \approx 20,000 \text{ Pa s}$ with $\dot{\epsilon}$ from 40 to 100 s^{-1} .

DR J. FERGUSON (Strathclyde) described improvements made to the spin-line rheometer. Values of η_E increased as $\dot{\epsilon}$ diminished. η_E from 100 to 10,000 Pa s (depending on position along the fibre). The pendant drop experiment showed no "bounce" (as was found with M1) and η_E ranged from 800 to 1000 Pa s.

DR R. GUPTA (Buffalo) described the vacuum stretching of a filament. A steady state is obtained and the stress can be related to a pressure head of water. η_E reached a maximum of 10^3 Pa s with distance along the filaments. A Maxwell model best described the results with a relaxation time of 0.35s.

DR H. W. BEWRS DORFF (Dortmund) investigated the effect of pre-shearing (in a Couette flow) on η_E (determined orifice flow). In general there did not appear to be much effect of pre-shearing. [η_E for A1 in range 200 to 400 Pa s.]

DR D. R. OLIVER (Birmingham) applied the method used to determine η_E of M1 (see Ref. 1) to determine that for A1, a modified filament stretching but in the horizontal plane. A value of around 1000 Pa s was found for η_E . The material became "solid" like when the filament was wound on the drum at a velocity of 50 mm s^{-1} .

MR M. COUCH (Aberystwyth) described his work on the spin-line experiment and with the open syphon. Several results were taken at different thread lengths and for different flow rates. Observed values of η_E depended on these quantities which encompassed a strain of from 2 to 10 and strain rates of 2 to 10 s^{-1} . The envelope of results overlapped each other and those from Jones' falling pendant drop (see above). Mr Couch also referred to Dr D. M. Binding's results with the capillary contraction and outlined Binding's molecular interpretation which pointed to a molecular weight of 6×10^6 for the solute molecules.

PROFESSOR P. BRUNN (Erlangen) described results on the flow through packed beds, where elongational flow is not entirely uniaxial, and contractions and expansions occur in sequence in the flow. As the rate of flow increased η_E increased, but then at sufficiently rapid flow, η_E decreased abruptly.

PROFESSOR C. CHNIELEWSKI (Michigan) described the flow of various fluids through a permeability cell (porous medium) and discussed the effect of molecular weight and other physical properties of the fluid. Different arrays of pores were used. A laser anemometer had been used to scan the array.

DR U. CARTALOS (Grenoble) discussed fluid models with interactions and their capability of predicting Newtonian flows and the modifications introduced by elastic fluids, particularly with regard to the lip vortex and the corner vortex in contraction flow.

DR E. MITSOULIS (Ontario) applied the BKZ fluid model to contraction flow (4:1 and 16:1 contractions). The corner problem in numerical analysis was discussed.

MR R. KEILLER (Cambridge) applied the Oldroyd B model to the various flow results obtained with fluid M1. A satisfactory theoretical interpretation was given of the falling pendant drop, the open syphon, the spin-line and Oliver's horizontal filament (see above).

PROFESSOR G. LEAL (California) described 2-D birefringence in a four-roll mill. The birefringence occurred over 50μ . A1 degraded (velocity gradient $26s^{-1}$). $1s^{-1}$ will give faint birefringence. The system took 20s to reach equilibrium (relaxes in 1s). Birefringence only occurs close to the stagnation point.

DR K. TE NIJENHUIS (Holland) gave a resumé of results obtained in the oscillatory mode and also in Ubbelohde viscometer (capillary). Relaxation time 8.5s.

Dr T. E. R. Jones summarised the results reported on shear flow and Dr N. Hudson summarised those on elongational viscosity. Dr Ferguson pointed out the various factors determining the value of η_E and presented a 3-dimensional display of η_E as a function of these factors. Gupta pointed out there were various ways of arriving at a given final state and even with discrepancies between values of η_E any particular technique could yet be valid in quality control. Professor Walters said the disagreements are no longer controversial but emphasised that the relevant variables [strain, time (pre-history) and strain rate] should be stated for future work. Should another meeting be held to discuss it?

REFERENCE:

1. Extensional Viscosity Determination for the Test Polymer Solution M1 in JNNFM 35 (1990).



Some of the delegates at the Villard-le-Lans meeting.
 Foreground, left to right Dr J. Ferguson, Prof. K. Walters, Prof. C. Wolff,
 Mrs Piau, Prof. J-M. Piau, the Mayor of Villard.

COMMENTARY ON 264TH COUNCIL MEETING

Nine Council members eventually found the small basement room in a motel in West Bromwich. Before formal proceedings commenced members compared the lengths of their journeys home following the last Council meeting in Welwyn. The record was forty-four hours, only slightly less than the time taken that morning for the same member to find the access to the West Bromwich Moat House once he had sighted the place from the motorway. Anthony stated that he thought he had said too much at the last Council meeting. He intended to do the opposite at this one by way of penance.

As a further contribution to efficiency the President had a timetable for the meeting. This, however, failed to survive item 3, matters arising, which took one hour and ten minutes. Some of this time was spent on a post-mortem on the one-day meeting on elongational viscosity which was to have been held the week before, but which had to be cancelled due to a poor response. One Council member, who shall remain nameless, offered the view that a lack of interest from industry in particular was not suprising. It, i.e. industry, was only just becoming dimly aware of "recent advances" like viscoelasticity and dynamic measurements, and could not be expected to discover elongational flows for many years to come. This view went unchallenged, this should not however be taken as an indication that the rest of the Council shared the opinion, even if the other industrial members, including myself, were too timid to speak up. Does anyone want to buy a second-hand elongational viscometer?

There was some doubt as to what constituted an "action" and how such were indicated in the minutes. In future these would be emphasised by means of very big initials in the margin.

The Treasurer reported that the Society had made a small loss in 1990. A much larger deficit had been allowed for by way of support for the Golden Jubilee Conference and so the outcome was very satisfactory. The need to register for VAT had proved to be a good thing since £5000 of VAT had been recovered. In the near future the Society will, like TESCO, be able to take payments by credit card. Unlike TESCO it will not be selling skinny, yellow chickens at twice the price per pound of fat, white ones. The Society is not of course in the business of selling poultry, nor Society ties it seems, which produced no income in the last half-year. A suggestion that there might be a Society cloth-cap for northern members was quickly suppressed. Apparently there had once been an organised northern faction. A suggestion from a long-standing member that Council might like to support informal, local meetings was however well received.

The reports of the Bulletin and Abstracts Editors now gave the rest of the Council a chance to pretend that they are *au fait* with the details of word-processing and modern publishing technology. The Abstracts Editor is currently negotiating with ISIS and ASLIB to obtain theses' abstracts. Council also pretended that they knew what these acronyms signify, although the expressions on some faces suggested the contrary. It was proposed that a complete history of the Society should be commissioned, a distinguished past-member of Council is to be approached. It was thought he might find the job a nice change from writing obituaries.

A study-group was set up to define the composition and remit of a working-party to be formed to prepare a Handbook of Rheological Terms. The handbook will define and explain more important rheological terms and concepts at a level understandable by an intelligent sixth-former. A similar group will define the terms of reference of a working-party to address "transparency in software and rheometer operation". The purpose of the latter initiative was a source of some confusion but no doubt the study-group will clarify all in good time.

As usual the business of the Society was carried out in a constructive and friendly atmosphere. Anthony kept to his promise to be succinct. The contributions he did allow himself were appreciated and were tempered with the experience and concern with the traditions of the Society one might expect.

Richard Buscall

A NOTE ON MEMBERSHIP FEES

Membership fees are due on October 1st each year. At its last A. G. M. the Society decided to increase the annual subscription fee as follows:

Payment by **Standing Order** or by **Credit Card**, provided it is received within 3 months of the due date: £10

Payment received after January 1st: £15

Payment by cheque or cash: £15

The necessary form for payment by standing order or credit card is enclosed with this Bulletin and please note that existing standing orders must be amended to ensure the new rate is paid.

D. J. Hourston
Membership Secretary

NOTICE OF THE ANNUAL GENERAL MEETING

The 51st Annual General Meeting of the British Society of Rheology will be held on Tuesday September 10th 1991 in Wills Hall at the University of Bristol, starting at 4.45 p.m..

Members are reminded that, under rule 7(b), the business of the meeting includes:

(a) The election of Officers (other than President) and Council Members for 1991-92.

(b) The receipt of a report and audited accounts from Council.

(c) Dealing with matters raised by Council or by any Member, and receiving suggestions from Members for consideration by Council.

Nominations received to date are as follows:-

(President:	Dr D. C. H. Cheng)
Honorary Secretary:	Mrs C. A. Moules
Honorary Treasurer:	Mr P. C. Anderson
Membership Secretary:	Dr D. J. Hourston
Bulletin Editor:	Dr P. F. G. Banfill
Abstracts Editor:	Dr G. J. Brownsey

Ordinary Members of Council:

Dr R. Buscall
Mr R. E. Carter
Dr A. Evans
Dr N. Hudson
Dr M. Mackley
Prof. P. Townsend

Nominations for Council or for any of the Offices are invited. Nominations should be sent to the Secretary or may be made at the meeting (see rule 5(b)).

The Secretary would be pleased to receive notice of any matter that any Member wishes to raise.

C. A. Moules
Honorary Secretary

THE SCOTT BLAIR COLLECTION
CATALOGUE SUPPLEMENT NO 1

A SUPPLEMENT OF ADDITIONS AND AMENDMENTS TO THE CATALOGUE THE
MONOGRAPHS, PAMPHLETS AND JOURNALS OF THE BRITISH SOCIETY OF
RHEOLOGY'S SCOTT BLAIR COLLECTION, DEPOSITED IN THE HUGH OWEN
LIBRARY, UNIVERSITY COLLEGE OF WALES, ABERYSTWYTH.

The original catalogue was published in the Bulletin 1989, Vol. 32,
No 2 pp. 56-83. Supplement No 1 contains additions up to January 1991.

ADDITIONS AND AMENDMENTS :-

Advances in rheology; edited by Baltasar Mena. . . see International
Congress on Rheology, 9th, Acapulco, 1984.

Bogue, Donald C. *Engineering analysis of non-Newtonian fluids*, by
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Shelved with the journal.

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JOURNALS

British Rheologists' Club bulletin no. 15 1947–no. 27 1950.

British Society of Rheology bulletin no.28 1950–

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RECENTLY PUBLISHED BOOKS

This is the first of an occasional series listing books which might be of interest to members. Council recently decided that Book Reviews should continue to appear in *Rheology Abstracts* but that the bare factual information should be given in the Bulletin. We hope this list, which revives a previous practice, is useful. It would help if members could pass any information they find to the Editor.

The Physics of Fluid Turbulence, W. D. McComb, Oxford Engineering Series 25, Oxford University Press, ISBN 019-856160-1, pp. 572, 1990, £75.

Foundations of Colloid Science, Volume II, R. J. Hunter, Oxford University Press, ISBN 019-855189-4, pp. 424, 1989, £55.

Sol-Gel Science, C. J. Brinker, G. W. Scherer, Academic Press, ISBN 012-134970-5, pp. 928, 1990, £99.50.

Outlines of Paint Technology, W. M. Morgans, Edward Arnold, ISBN 085-264308-x, pp. 503, 1990, £50.

THE GOLD MEDAL OF THE SOCIETY

This note is a brief history of the Society's Gold Medal which has been awarded twelve times since its inception in 1966.

The medal itself has the Society's emblem on the obverse and a brief citation on the reverse. An emblem had been proposed informally on several occasions, but positive steps were taken only when the first presentation had been decided upon. The Society approached the Council of Industrial Design and Richard D. Gransby was suggested as a "graphics designer of the quality, calibre and experience to produce a drawing for subsequent translation by a medallion firm into a medal". He discussed it with Professor A. J. Kennedy, the then President, and R. J. Cole, the then Secretary, and produced a simple design, capable of reproduction over a range of sizes and incorporating symbols appropriate for a rheology society. The resulting emblem is well known to all members and many others, appearing on publications and stationery.

PROFESSOR MARKUS REINER was the first recipient of the medal which was a special award in recognition of his classic contributions to the study of rheology and to honour his 80th year. The award was made at a special dinner in his honour, at which he described how his work as a civil engineer in the 1920s brought him into contact with Professor Bingham, a chemist. Together they decided to form a small group of those interested in deformation and flow and, in consultation with the Professor of Classics, coined the word 'rheology'.

The second award of the medal established the principle of it being for Applied Rheological Research. A competition was held with the aim of encouraging workers to make greater practical use of fundamental rheological principles. After no award was made in 1967, the competition was held again in 1969 and the paper by PROFESSOR D. DOWSON and PROFESSOR G. R. HIGGINSON entitled "The Role of Lubricant Rheology in Engineering Applications of Elastohydrodynamic Lubrication" was awarded the medal. Their work established a bridge between rheology and tribology, a term which had at that time only recently been applied to the science of solid/solid contacts.

The following year, the Society's 30th anniversary was marked by special gold medal awards to the two surviving founders of the Society, DR G. W. SCOTT BLAIR and DR V. G. W. HARRISON, H. R. Lang, the third founder, having died some years previously.

By now the gold medal competition had been abandoned and awards were made by a panel of the current and previous two Presidents. The first medal awarded under this arrangement was to PROFESSOR L. R. G. TRELOAR.

This was for his significant contribution to the solution of major industrial problems by the application of fundamental rheological knowledge in the fields of rubber elasticity and polymer science.

After a long interval, PROFESSOR J. G. OLDROYD was the next metallist in 1980, in recognition of his classic papers on theoretical rheology which were generally agreed to represent thinking several years ahead of other workers in the field and to provide a fundamental framework for much subsequent work.

The gold medal awarded to PROFESSOR A. S. LODGE in 1983 was for outstanding contributions to rheology, including theoretical rheology, his book *Elastic Liquids*, and his work on evaluating and minimising errors in experimental measurements.

In 1984, a gold medal was awarded to PROFESSOR K. WALTERS. Some felt that the award, in recognition of his work on the flows of non-Newtonian liquids in simple geometries and on numerical methods, was overdue.

The next gold metallist was PROFESSOR J. R. A. PEARSON. His early work was on low Reynolds number flow past obstructions and on the instability of flow under rollers and spreaders. Later major topics were fibre spinning and screw extrusion, which made major contributions in his campaign to bring rheological principles into use in the polymer processing industry.

Finally, to celebrate the Society's Golden Jubilee, two gold medals were awarded in 1990. SIR SAM EDWARDS has wide research interests including the shape of polymer molecules in solution and turbulence but his main contribution to rheology is the theory of reptation which he developed with Doi as the molecular basis for the flow of polymers. PROFESSOR HANS-WALTER GIESEKUS has done distinguished work on the development of constitutive equations and is known to all rheologists as editor-in-chief of *Rheologica Acta*.

There having been twelve metallists in 24 years there is unlikely to be another award for three or four years, but with the present healthy state of rheological research we can be assured that worthy candidates are not far away. Whoever they are they will certainly have been influenced, and probably supervised, by one of the eminent people described in this note.

Citations, longer descriptions or relevant articles have appeared in the Bulletin as follows: Reiner (1966) (3) p.1; Dowson and Higginson (1969) 12 (4), Supplement pp.1-23; Scott Blair (1970) 13 (4), pp.113-115; Harrison (1970) 13 (4), p.111, photograph only; Treloar (1972) 15 (4) p.69; Oldroyd (1981) 24 (1), p.3, but see also 24 (2), pp. 21-27; Lodge (1983) 26 (4), pp.61-63; Walters (1984) 27 (4), pp.59-61; Pearson (1986) 29 (3), pp.33-35; Edwards (1990) 33 (3), p.62; Giesekus (1990) 33 (3), p.62

MEMBERSHIP NEWS

The following applications for membership were approved at the Council Meeting, March 14, 1991.

Dr M. J. Adams
Unilever Research
Port Sunlight Laboratories
Quarry Road East
Bebington, Wirral
Merseyside L63 3JW.
(etsa ADEGHIL)

Dr B. Babatope
Chemical Engineering Dept.
University College
Singleton Park
Swansea SA2 8PP.
(fetsa G)

Dr A. C. Diogo
CFMC-Av. Gama Pinto
1699 Lisboa Codex
Portugal.
(fetsa CDE)

Dr M. Djabourov
Ecole de Physique et Chimie
10 Rue Vauguelin 75231
Paris Cedex 05
France.
(pets DO)

Mr M. Fryars
Kobe Steel Europe Ltd.
10 Nugent Road
Surrey Research Park
Guildford
Surrey GU2 5AF.
(tersa BCDH)

Mr S. Handley
Mettler-Toledo Ltd.
64 Boston Road
Beaumont Leys
Leicester LE4 1AW.
(fets ABCDEFGHIJKLMN)

Mr I. P. Whelan
The Merrell Dow Research Institute
Reading Road
Winnersh, Berks.
(fpetsa FGHN)

Dr Howard Barnes, Unilever Research, has been appointed an Honorary Professor in the Department of Mathematics, University College of Wales, Aberystwyth.

Dr Neil Cogswell has retired early from ICI Advanced Materials. He has served the Society as Council Member and was President from 1986 to 1988. We wish him well in his retirement. Professor Ken Walters has been elected Fellow of the Royal Society. We offer him our warmest congratulations on this honour, which, as far as we know, is the first F. R. S. in recognition of entirely rheological research.

COMPETITION NO 3

Competition No. 2 attracted more entries than did No. 1. The winning efforts are:

A flow that is called elongational
Occurs in a tube convergational
It exists with a shear
In a way that is queer
Defying the seers calculational

by Ken Hawes of Sunbury-on-Thames, who wins a BSR tie.
and

An intelligent maiden called Nell
Whilst inventing a new type of gel
Had a viscous affair
When it caught in her hair
And cleared up her dandruff as well.

but, unfortunately

This winner's a real modest guy
For some reason, I don't know why
He gave us no name
If he'll submit a claim
We'll send him a BSR tie.

Commended is the entry from D. Morgan of Malvern, into which an extra word has been inserted to improve the scansion.

An eminent Dean of Theology
Decided to study rheology
But because of the strain
Of this stress on his brain
He opted instead for geology

Competition No. 3 is to make as many words as possible, each of 5 letters or more, from the letters of the word

VISCOMETER

Each letter of 'viscometer' may be used only once (but 2 Es) in a word. Use of S as the last letter to form a plural or the 3rd person singular of a verb is not permitted. Lists *must* be in alphabetical order. In case of doubt, the OED will be used for decision. No proper nouns, trade names, or slang. If you send an entry, it will be assumed that you have not been assisted in any way by a computer except that you may use a word processor to put words in alphabetical order.

Entries to: Dr G. H. Tattersall, 174 Millhouses Lane, Sheffield S7 2HE.
Closing date June 15th, 1991.

As usual, a BSR tie or £5 book token for the winner.

Because despatch of some copies of the last issue of the Bulletin was unfortunately delayed, the closing date for Competition No. 2 was put back. We apologise to any members who were deterred from entering.

CONFERENCE ANNOUNCEMENTS

ENGINEERING RHEOLOGY

THE ANNUAL CONFERENCE OF THE BRITISH SOCIETY OF RHEOLOGY

at The University of Bristol

September 9-11th 1991

Papers are still being accepted for this meeting. Titles and Abstracts of around 200 words should be sent to Roy Carter as quickly as possible please. Please note that, to reduce the price of the Conference, the meeting will now finish on September 11th rather than 12th and the Proceedings will not be published but papers may be submitted for a special edition of a suitable Journal.

Papers received to date include the following

Dr G. Robinson, Krüss U. K.: "Rheological Characterisation of Manufactured Materials"

Dr P. F. G. Banfill, Liverpool University: "Experimental Investigations on the Rheology of Fresh Mortar"

Drs J. C. Craven & A. L. Hudd, Domino Amjet Ltd.: "The Rheological Properties of Continuous Ink-Jet Printing Inks"

Dr J. Ferguson, University of Strathclyde: "Measurement of Dynamic and Steady Shear Flow Using an On-Line Process Control Rheometer"

Dr F. S. Baker and R. E. Carter, Carter Baker Enterprises Ltd.: "Curing Properties of Powder Coatings"

A. George, Porpoise Viscometers: "The P1 Reaction Viscometer"

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Members of the BSR:	£210.00
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Non-Members:	£240.00
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Bona Fide Students:	£150.00
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Those wishing to Register for the Meeting should complete the form below and return with full payment in Sterling as quickly as possible.

Name: Affiliation:

Address:

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Tel: Fax: Telex

Notes: (Arrival times, special dietary needs, etc.):

Please return Registration Forms to Roy Carter, Carter Baker Enterprises Ltd., 2 Marshbrook Business Park, Church Stretton, Shropshire SY6 6QE, U. K., Tel.: 06946-466 Fax.: 06946-468 Telex: 9312102287 CB G.

EXTENSIONAL FLOWS IN INDUSTRY

Unfortunately the one day Conference which was to be held at the University of Strathclyde on March 6th, 1991 was cancelled through lack of support. The papers submitted for the meeting will be presented during a session devoted to this topic in the Society's Annual Meeting in Bristol in September.

DYNAMICS OF POLYMERIC LIQUIDS

AN INTERNATIONAL CONFERENCE

at

The Hotel La Residenza, Capri
September 11th-15th 1991

Sponsored by

The European Community and The University of Naples

SCIENTIFIC COMMITTEE: Prof. M. J. Crochet, Dr O. Hassager, Dr J. Hinch, Prof. R. I. Tanner, Prof. H. Winter.

THE LIST OF INVITED SPEAKERS INCLUDES: Prof. R. C. Armstrong (U. S. A.), Prof. A. N. Beris (U. S. A.), Prof. D. V. Boger (Australia), Prof. M. M. Denn (U. S. A.), Prof. M. Doi (Japan), Dr J. Ferguson (U. K.), Prof. D. D. Joseph (U. S. A.), Dr R. G. Larson (U. S. A.), Prof. L. G. Leal (U. S. A.), Prof. A. S. Lodge (U. S. A.), Prof. J. Mewis (Belgium), Prof. D. S. Pearson (U. S. A.), Prof. J. M. Piau (France).

COST: Half board for the nights of September 11th-14th, 1991 inclusive beginning with dinner on Wednesday 11th and ending with breakfast on the 15th. SINGLE: (very limited number) £325.00; DOUBLE: (used as single) £400.00; SHARED DOUBLE: £275.00. REGISTRATION FEE: (to include coffee breaks, conference dinner, etc.) £150.00 for participant; £50.00 for accompanying person.

A major part of the programme will be taken up with the invited lectures and extended discussion periods on topics of current interest. Time will also be set aside for contributed papers and poster presentations. It is intended to publish the Conference Proceedings as a Special Issue of the *Journal of non-Newtonian Fluid Mechanics*.

If you are interested in attending the conference please contact Professor K. Walters, Dept. of Mathematics, University College of Wales, Penglais, Aberystwyth, Dyfed SY23 3BZ, U. K..

MECHANICS OF NON-NEWTONIAN FLUIDS

A CISM RESIDENTIAL COURSE AT UDINE, ITALY

September 16-20th, 1991

Non-Newtonian Fluid Mechanics is an interdisciplinary science which is growing in stature as a scientific discipline and is seen as being of significant industrial importance. Many materials of industrial importance such as molten polymers, liquid detergents, paints and printing inks, are non-Newtonian and it is becoming increasingly important to be able to predict the behaviour of such materials in processing operations such as pumping, extrusion and moulding.

To cover the background material and provide a firm foundation requires an in depth study of Continuum Mechanics. However, there is an increasing awareness of the usefulness of molecular modelling and such a study complements developments on the continuum scale. Both approaches provide constitutive equations, which are of use in process modelling. Such modelling must rely heavily on numerical methods and "the Numerical Simulation of non-Newtonian Flow" is now seen as a very important and growing research area.

Non-Newtonian Fluid Mechanics is not just a theoretical pursuit, and, for a complete description on non-Newtonian behaviour, experimental studies are indispensable. These involve simple flows (i.e. Rheometry) and also flows in complex geometries of the sort one meets in industrial processes.

The course will present an in depth study of all the various threads, with the hope that an integrated and coherent picture will emerge of this exciting and important research field.

APPLICATIONS should be made to the Secretariat of CISM, Palazzo del Torso, Piazza Garibaldi 18, 33100 Udine, Italy.

TRAVEL GRANTS: A limited number of grants will be available to contribute to the expenses of attending this meeting. Members of the Society who are full-time students, may apply in writing to the Secretary as soon as possible to be considered for an award and that application should be supported by the student's supervisor. The application should give details of the proposed expenditure. The amount of each award will be at the discretion of the Council.

COMPUTER SIMULATION IN COLLOID SCIENCE

Details of a one day meeting to be held at the Scientific Societies' Lecture Theatre, London on May 15th, 1991 were recieved too late for inclusion in the last Bulletin but may nevertheless interest members.

Among papers to be presented were the following:

Particle Flocculation by Adsorbing Polymers, E. Dickinson, University of Leeds. Brownian Dynamics Simulation of the Rheology of Depletion Flocculated Dispersions, D. M. Heyes, University of Surrey. Investigations of Suspension Rheology via Isokinetic Steady-State Granular Dynamics Simulation, L. V. Woodcock, University of Bradford. Simulation of Aggregation under Shear, P. M. Rodger, University of Reading. Structure and Dynamics of Suspensions of Deformable Particles, M. J. Grimson, AFRC Institute of Food Research.

FURTHER INFORMATION may be obtained from: Dr R. Buscall, ICI Corporate Colloid Science Group, P. O. Box 11, The Heath, Runcorn, Cheshire WA7 4QE.

THE PROPERTIES OF CONCENTRATED SUSPENSIONS

Details of an afternoon meeting to be held at the Scientific Societies' Lecture Theatre, London on April 25th, 1991 were received too late for inclusion in the last Bulletin but may nevertheless interest members. The four lectures were to be as follows:

Stability/Instability and Rheology of Concentrated Suspensions, Dr Th. F. Tadros, ICI Agrochemicals, Jealotts Hill. Concentrated Dispersions, Professor R. H. Ottewill, University of Bristol. The Rheology of Dispersions of Strongly Interacting Particles, Dr J. W. Goodwin, University of Bristol. Aspects of the Formation and Stability of Emulsions, Dr E. Dickinson, University of Leeds.

FURTHER INFORMATION may be obtained from: Mr. S. S. Langer, The Royal Society of Chemistry, Burlington House, Piccadilly, London W1V 0BN

ADVANCING RHEOLOGY

A training course in rheological techniques will be held at the Post House Hotel, Cambridge on June 18-19, 1991. The course will show the use of both flow and deformation experiments to characterise real materials, through talks demonstrations and practical sessions. The course fee is £225 plus VAT. For further information contact: Karen Titmarsh, Krüss U. K. Ltd., 5/6 Carrington House, 37 Upper King Street, Royston, Herts SG8 9AZ.

HARDNESS AND NANO HARDNESS

A one day meeting will be held at Imperial College on July 15th, 1991, organised by the Tribology Group of the Institute of Physics. The hardness measurement is an old way of characterising the mechanical properties of solids and their surface regions. The deformation conditions under the indenter are complex and a hardness value cannot be simply related to a unique material deformation characteristic. About twenty years ago studies began of the hardness of solids at low load. Within the more recent past nano engineering has allowed even smaller loads to be applied. New experimental and analytical challenges have been added to the original problems. This conference will review the hardness measurement as a means of evaluating surface mechanical properties and consider the current state and future potential for these studies at the nano scale.

FOR FURTHER INFORMATION contact Dr M. J. Adams, Unilever Research Laboratory, Quarry Road East, Port Sunlight, Wirral, Merseyside L69 3JW.

INTERFACE PHENOMENA IN EXTRUSION AND FORMING OPERATIONS

The annual joint meeting of the the Tribology Groups of the Institute of Physics and Institution of Mechanical Engineers will be held at the Institute of Physics on September 19th, 1991. Intermediate or end products in a solid state are manufactured by a wide range of operations such as extrusion and forging. Many industrial sectors including metals, ceramics, foods, chemicals and detergents employ operations of this kind. It is well established that the traction at equipment walls has a profound effect on the viability of a process, the working loads and often the microstructure of the product. In order to account for such interactions and assist in optimising equipment design and operation, a number of analytical and numerical procedures have been developed. The meeting will focus on current approaches being adopted in hot and cold metal working and also in paste processing.

FOR FURTHER INFORMATION contact; Dr M. J. Adams, Unilever Research Laboratory, Quarry Road East, Port Sunlight, Wirral, Merseyside L69 3JW.

CONFERENCE DIARY

DATE	PLACE	DETAILS
28-31/5/91	Glasgow U. K.	Residential Course: 'Theoretical, Experimental and Industrial Aspects of Rheology', contact: Dr N. E. Hudson, Dept. of Pure & Applied Chemistry, University of Strathclyde, Glasgow G1 1XL.
18-19/6/91	Cambridge, U. K.	Short course: 'Advancing Rheology', contact: Karen Titmarsh, Krüss U. K. Ltd., 5/6 Carrington House, 37 Upper King Street, Royston, Herts SG8 9AZ.
4-5/7/91	University of Limerick Ireland	'Flow Processes in Composite Materials', contact: Dr C. M. O. Bradaigh, Dept. of Mechanical Engineering, University College Galway, Galway, Ireland.
7-12/7/91	Compiègne France	International Congress on Surface and Colloid Science, contact: Secretariat of the 7th ICSCS, c/o Wagons-Lits Tourisme, BP 244, F-92307 Levallois-Perret cedex France
15-18/7/91	Bristol U. K.	Residential School: 'Applied Rheology for Chemists', contact: Ms L. A. Hart, The Royal Society of Chemistry, Burlington House, Piccadilly, London W1V 0BN.
15-18/7/91	Prague Czechoslovakia.	'Rheology of Polymer Melts', contact: PPM Secretariat, c/o Institute of Macromolecular Chemistry, 16206, Prague,
16-19/7/91	Southampton U. K.	Clinical Haemorheology, Seventh European Conference, contact: Dr S. Roath, University Haematology, Room LF64, South Academic Block, Southampton General Hospital, Southampton SO9 4XY.
18/7/91	London, U. K.	'Hardness and nanohardness', contact: Dr M. J. Adams, Unilever Research Laboratory, Quarry Road East, Port Sunlight, Wirral, Merseyside L69 3JW.
9-12/9/91	Bristol, U. K.	International Conference on 'Engineering Rheology', Autumn meeting of the British Society of Rheology. contact: Mr R. E. Carter, Carter-Baker Enterprise 2 Marshbrook Business Park, Marshbrook, Church Stretton, Shropshire SY6 6QE.
11-15/9/91	Capri, Italy	'International Conference on Dynamics of Polymeric Liquids', contact: Prof. K. Walters, Dept. of Mathematics, UCW, Aberystwyth, Dyfed, U. K.

- | | | |
|-------------|---------------------|--|
| 15-18/9/91 | Palermo, Italy | Polymer Processing Society, European Regional Meeting, contact: S. Piccarolo, Dipartimento di Ingegneria Chimica, dei Processi e dei Materiali, Viale delle Scienze, 90128, Palermo, Italy. |
| 16-20/9/91 | Udine, Italy | 'Mechanics of non-Newtonian Fluids', contact: CISM, Palazzo del Torso, Piazza Garibaldi 18, 33100, Udine, Italy. |
| 17-19/9/91 | Leuven, Belgium | 'Interfacial phenomena in composite materials '91', contact: Janet Miles, Conference Organiser, IPCM '91, Butterworth-Heinemann Ltd., PO Box 63, Westbury House, Bury Street, Guildford, Surrey GU2 5BH. |
| 18-20/9/91 | Brugge
Belgium | 7th European Congress on Mixing, contact: c/o TI-K.VIV, Attn. Ms Rita Peys, Desguinlei 214, B-2018 Antwerpen (Belgium). |
| 19/9/91 | London, U. K. | 'Interface phenomena in extrusion and forming operations' contact: Dr M. J. Adams, Unilever Research Laboratory, Quarry Road East, Port Sunlight, Wirral, Merseyside L69 3JW. |
| 9-12/10/91 | Beijing, China | China-Japan International Conference on Rheology contact: Chun Fan, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100080, China. |
| 16-18/12/91 | Southampton, U. K. | 'The Conformations of flexible molecules in fluid phases', Faraday Symposium 27, contact: Mrs. Y. A. Fish, The Royal Society of Chemistry, Burlington House, Piccadilly, London W1V 0BN. |
| 9/4/92 | London, U. K. | 'Rheology of Building Materials', contact: R. J. Mangabhai, TH Technology, Maple Cross House, Denham Way, Rickmansworth, Herts. |
| 17-22/8/92 | Brussels
Belgium | 9th International Congress on Rheology, contact: Dr P. Moldenaers, Chemical Engineering Department, Katholieke University Leuven, W. de Croylaan 46, B-3001 Leuven, Belgium. |

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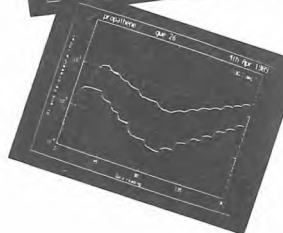
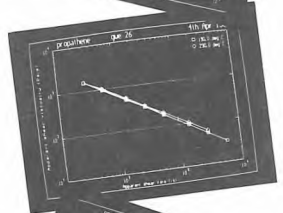
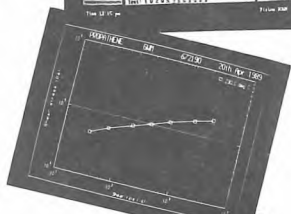
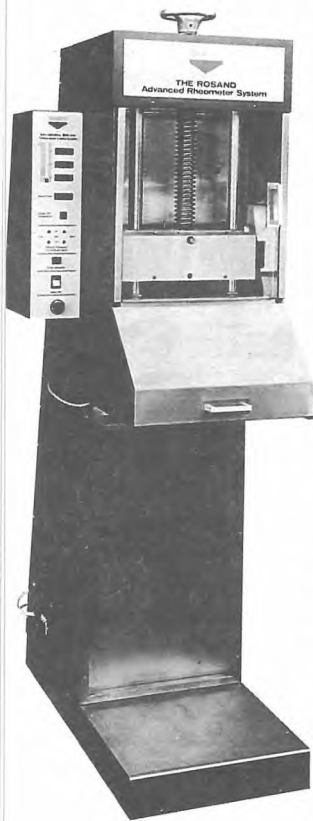
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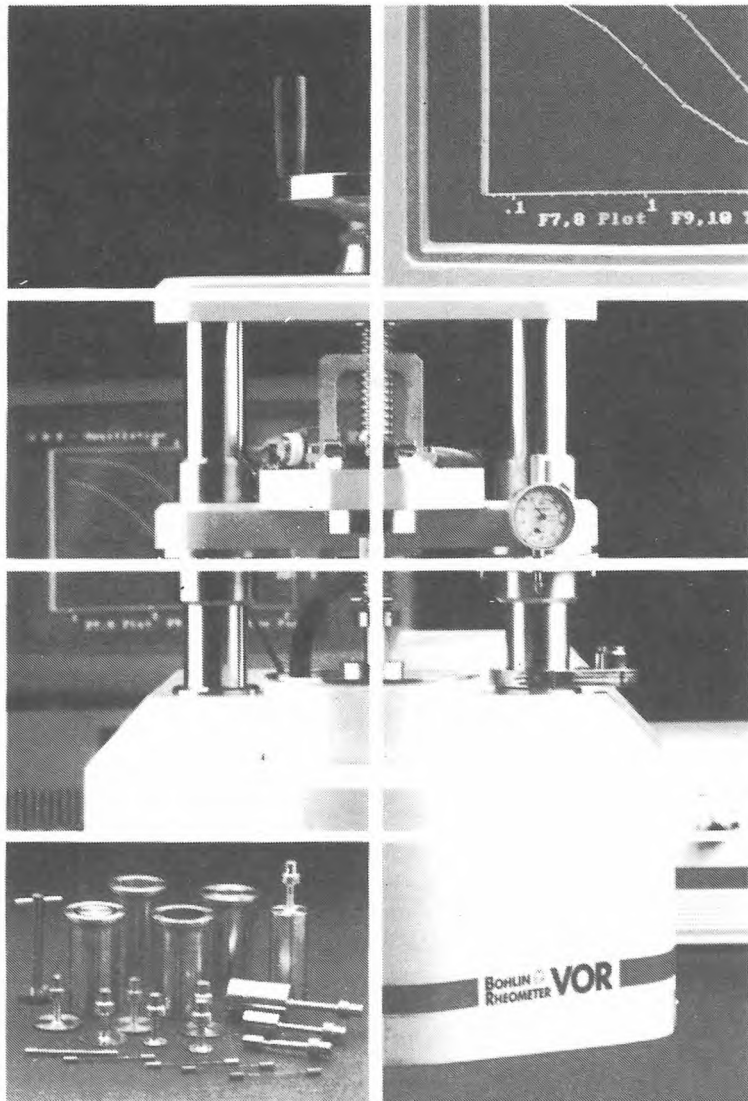
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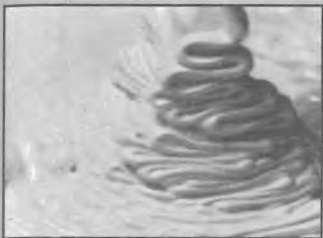
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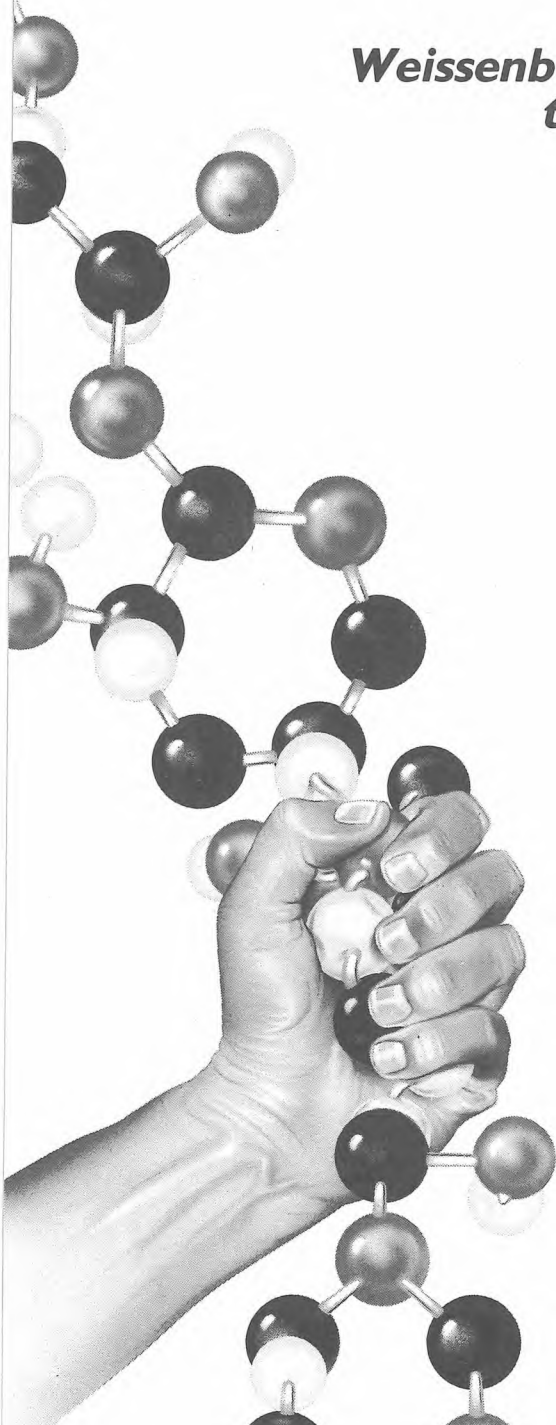
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