

BULLETIN



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Hon. Editor:

M. CAMINA,

Paint Research Association,

Waldegrave Road,

Teddington,

Middlesex.

FOREWORD

In answer to a technical enquiry, Dr. J. Benbow has written an informative article on the "Rheology of Pastes", a subject of importance to many industries. Articles or notes from workers in this field would be very welcome.

More browsing: Twenty-five years ago, the President, L. R. G. Treloar (Bulletin No. 40, April '74) finished his written comment with this paragraph:

"One may perhaps be permitted to draw the conclusion that the attitude of exclusiveness engendered by a proper pride in the methods and discipline of one's own subject may be carried too far, to the detriment of the process of cross-fertilization from which new scientific concepts so frequently germinate. Rheology in particular draws widely on knowledge and experience gained in many other fields of activity—physics, chemistry, biology, engineering and a variety of industrial technologies—and it has always been a primary concern of our Society to bring together workers in all these fields. Rheologists may thus be well placed to take advantage of new and helpful concepts as they arise, for it is only by the development of new concepts that a science remains vigorous and alive."

OFFICERS AND MEMBERS OF COUNCIL, 1978-1979

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DR. D. MARSHALL, Institute of Polymer Technology, Loughborough University of Technology, Loughborough, LE11 3TU.

DR. D. R. OLIVER, Department of Chemical Engineering, University of Birmingham, Birmingham.

NOTICE OF THE ANNUAL GENERAL MEETING, 1979

The 39th Annual General Meeting of the British Society of Rheology will be held on Thursday, 13th September, in the Common Room of Pontycelyn Hall of Residence at 17.45.

Members are reminded that (Rule 7(b)) the business of the meeting includes

- (i) The election of officers and other members of Council.
- (ii) The receipt of a report and audited accounts from Council.
- (iii) 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:

<i>Secretary</i>	Dr. C. J. S. Petrie
<i>Treasurer</i>	Mr. A. Evans
<i>Membership Secretary</i>	Dr. D. C.-H. Cheng
<i>Editor (Abstracts)</i>	Mr. J. Astin
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	Mr. F. N. Cogswell
	Dr. T. E. R. Jones
	Dr. D. E. Marshall
	Dr. D. R. Oliver

The President, Dr. W. M. Jones, holds office until 1980. Nominations for Council or for any other offices (other than President) should be sent to the Secretary (or may be made at the Annual General Meeting in accordance with Rule 5(b)).

The Secretary would be pleased to receive notice of any matters that any member wishes to raise.

C. J. S. PETRIE

May 1979

THE RHEOLOGY OF ASSOCIATING, STRUCTURED AND BIOLOGICAL SYSTEMS

Joint meeting of the British, Italian and Dutch Societies of Rheology, Amsterdam, 18th-20th April, 1979.

The Grand Hotel Krasnapolsky provided a colourful setting for this meeting, most participants travelling daily by foot or tramcar from smaller hotels in the inner city. This provided regular views of the famous canals of Amsterdam, which near the centre form five semi-circles around the main square, with radial roads and walkways crossing the canals at regular intervals. Papers were presented in a cheerfully-decorated salon in the Grand Hotel, which also provided the venue for the cocktail reception and conference dinner.

The attendance of around 80 was rather less than the organisers had hoped for, with about 33 Dutch, 18 British and 12 Italian participants. This shows that other countries made a significant contribution to the success of the meeting.

The first session involved an interesting variety of papers on biological systems. G. Pezzin of Bologna compared the mechanical properties of fibrous and semi-crystalline proteins, which carry loads in the body, with those of synthetic rubbers, finding similarities in the stress-strain behaviour. Some proteins were more like composite materials in character. A paper by G. Miller of Louisville showed how the sack which surrounds a baby in the womb has viscoelastic properties and how cyclic pressure variations eventually lead to local weakness and rupture; in the same area, J. Klein of Israel studied the diffusion of proteins in the umbilical cord. Still in the "solid" field, most of the audience was surprised to hear that human tooth enamel contains channels between the fibres through which liquid exudes when pressure is exerted on the tooth (P. G. Fox, of Nottingham). This behaviour, rather like that of a stiff sponge, greatly increases the toughness of the material. The presence of fluoride ions in the hydroxy apatite layer was also shown to increase the toughness of the tooth. C. A. Street of York posed the question "why did the orange pastille lose its shape?" rather than "why do fruit pastilles decay the teeth?" A graphical presentation was used to show how blackcurrant pastilles survive almost any storage conditions whereas orange pastilles drain away unless stiffened with extra gelatin! Miss Zerbini of Milan was, however, interested in the quality of her Golden Delicious apples. Compression tests on whole apples were performed for three separate harvests, with samples from the Po Valley and from the mountains nearby. It seems as though the mountainous terrain produces firmer apples.

Professor Silberberg of Israel presented an absorbing study of epithelial mucus movement, using as a model a mucus-depleted frog palate. It was found that, to function properly as a transporter of

fine particles, the substitute mucus should behave as an incipient gel and the ciliary hairs beat with a frequency of 1-10 Hz. Three papers were devoted to viscous flow measurements, F. M. Leslie of Strathclyde dealing with the topical subject of liquid crystals, I. D. Evans of Sharnbrook with gelatinised starch suspensions and S. Gravsholt of Denmark with detergent solutions. The latter solutions were viscoelastic in character and showed the phenomenon of rheopexy under certain conditions of shear.

On Thursday morning, N. Casson of Loughton presented an excellent paper on suspension rheology in which liquid immobilised on the surface of rough particles and within aggregates was studied. Aggregates were physically made from small spherical particles and used in suspensions for viscosity tests. The stagnant liquid increased the effective solids concentration by a factor of 1.2 to 2.3, but for suspensions of pigment in oils this figure decreased as the shear stress or solids concentration increased, the product of these quantities controlling liquid immobilisation and hence suspension viscosity. In studying the thixotropy of bentonite-water dispersions, D. Cheng of Stevenage used both a rheogoniometer and the Warren Spring "Gun Rheometer". Here the bullets were not verbal ones but long-term gelled suspensions! Other papers dealt with the thermodynamic approach to viscoelasticity and the settling of aggregated red blood cells under varying conditions of shear, the latter being an extra paper submitted by your correspondent.

The only bright, sunny day saw afternoon visits to either Dutch villages, or a fine parkland area close to the bulbfields—the Keukenhof. The cold weather had delayed most outdoor flowers, but in the extensive greenhouses the variety of tulips in full bloom was remarkable. Most species seemed to have English names! At the conference dinner in the evening, welcoming speeches were made by the host nations, including one by our new president, Mervyn Jones. In a light moment he mused on the fate of a Welshman, a Scotsman and an Irishman, keeping his thoughts on the Englishman to himself!

The Friday session, devoted to synthetic polymer systems, opened with a paper by H. Janeschitz-Kriegl of Linz. Starting on the basis of the stress optical rule, he showed that the complex structure of polymer melts leads to a large time gap between short- and long-range conformational changes. A relaxation time at the glass transition temperature T_G may be 10^{13} times higher than one observed at a temperature 100°K above T_G , thus at the temperature T_G a "frozen in" chain orientation will show no signs of relaxation within a reasonable time. The paper is linked to one by G. Marucci, of Naples, by the concept of chain "reptation", in which a snake-like macromolecule is considered to be confined within a virtual tube, determined by the nature of the entanglements between molecules.

Experiments on the stretching of PMMA above its glass transition temperature were made up to length ratios of over 3.5 and it was shown that stress relaxation occurred at significantly higher rates as the length ratio increased. The remarkable linearity between stress and length ratio at high extensions suggested that the confining "tube" was itself modified by the stretching process, possibly on a constant-volume basis. The melt spinning of poly- ϵ -caprolactam was described by D. Acierno of Palermo and papers on the creep behaviour of polymers were presented by G. Rizzo of Palermo and by A. Marchetti of Pisa.

In examining the non-equilibrium extension, at constant pulling speed, of various classical elastomers, J. Ibar of Ballainvilliers showed that different mechanisms existed when the strain was respectively above and below 40 per cent. J. M. Dealy of Delaware tested various commercial polyethylenes in a device in which the shear rate could be held steady or changed in a stepwise manner. This led to the important conclusion that the time scale for structure reformation could be an order of magnitude larger than that for stress relaxation. Such "structural memory" effects may be an important feature of the behaviour of any solution or melt with a complex molecular structure. In the same group of lectures, W. M. Jones of Aberystwyth showed how the relatively elongated, rigid, "Kelzan" molecule yields different solution properties from the flexible, folded polyacrylamide structure. These differences were highlighted in viscosity measurements, in Taylor vortex flow and in flow through porous structures. However, they did not extend to drag reduction and to the stability of pipe flow, which were similar for both types of solution.

The organisers of the meeting, Dr. Booij and Dr. Daum, are to be congratulated in providing an informative lecture programme in surroundings which will be remembered by all participants.

D. R. OLIVER.

CONFERENCE ON CHEMICAL ENGINEERING RHEOLOGY

**held at The Rhine Westfalia Technical University, Aachen
under the auspices of the Deutsche Rheologische Gesellschaft
(the German Society of Rheology)**

5th-7th March, 1979

There were 22 papers presented in English at this conference: these are briefly reviewed below:

1. "Extensional flow experiments with lubricated dies" by C. W. Macosko and H. H. Winter.

This paper was essentially a survey of work being carried out jointly at Minnesota and Stuttgart on the effect of lubrication on extensional flows. A large number of results were presented very quickly. Anyone interested in this line should contact the authors.

2. "Elongational behaviour of polymer melts" by M. H. Wagner.
The author presented a modified network theory.
3. "The stability of stretching flow of polymer melts" by H. P. Hurlimann.
This paper dealt with the die inlet problem and looked at the instabilities that occur.
4. "Scale-up of thixotropic pipe flow" by D. C-H. Cheng.
A general discussion on scale-up problems: seemed to be limited to power law materials.
5. "A comparison of shear and extensional melt rheology" by C. W. Macosko.
A highly optimistic paper with no real progress to justify the author's claims.
6. "Rheological characterization of thixotropic fluids" by Z. Kemplowski.
The author examined the problem of oscillatory motion imposed on a steady shear. Very little actual progress was reported.
7. "Turbulent transition in pipe flow" by G. Berg.
The author gave the mathematical analysis for several ideal fluids and concluded that pipe flow was stable. Experiments do not confirm this.
8. "Turbulent structure in viscoelastic liquids" by W. Thielen.
A superb experimental paper using laser techniques for velocity measurements.
9. "Effect of additives on the structure of turbulence in a mixing layer" by M. Kwade.
A nice experimental set-up to examine the mixing of two streams with different velocities.
10. "Power characteristics of some agitators" by G. Langer.
The question of whether polymer additives help in mixing problems was discussed in detail and it seems that sometimes they do and sometimes not (!?)
11. "Hydrotransport of coal in pipes—the influence of high molecular weight additives on pressure drop" by J. Golda.
A very interesting paper on large scale work being carried out at Dortmund. Anyone in this field must contact the author.
12. "Contribution to the interpretation of the non-Newtonian behaviour of polyox in dilute aqueous solutions" by C. Wolff.

This paper was very difficult to follow but seemed to have some connection with the analysis of sheet thickness by birefringence techniques.

13. "Growth of a vitrified layer during injection moulding" by H. Janeschitz-Kriegl.
A beautiful and idiosyncratic review of work already published in *Rheologica Acta* 1977.
14. "The continuous flow squeeze film" by K. Gooden.
The only all mathematical paper in the conference. This was a full numerical study using an Oldroyd 6-constant model of the continuous squeeze film.
15. "Diffusion of CO_2 in non-Newtonian suspension" by P. Mitschka.
An interesting review paper.
16. "Laminar flow of concentrated suspensions in capillary viscometers" by M. Buchtelova.
An interesting paper on particle migration.
17. "Stability of coating flows of viscous and viscoelastic liquids" by S. Middleman.
A paper which had slight comic overtones by virtue of the fact that the speaker was also the session chairman. However, a very good review of stability and ribbing problems in coating.
18. "Dimensional analysis for flow problems in cooled channels" by R. Schulze-Kadelbach.
A paper which was extremely difficult to follow.
19. "Shear deformation exerted by a roll mill upon rubber compounds" by Tet Sou Ng.
A very clear outline of the problem of prediction of the thickness of a rubber sheet which has passed through a roll mill: no clear solution, however.
20. "Melt flow control in sheet extrusion" by D. Michaeli.
A careful and detailed account of the use of a computer in on line flow control.
21. "Flow properties of mineral filled polymers" by G. Menges.
A very early report of work in progress in Aachen.
22. "Normal stress measurements" by W. Heinz.
A report of work using a modified rheometry. Very sparse on information.

The conference was very enjoyable with everyone being extremely friendly. There did, however, seem to be a lack of organisation. I did not receive any information until I arrived off the train at 8.30 a.m. on Monday; a list of participants was not available until Tuesday; there were no abstracts of the papers and no meals or refreshments provided for the conference fee of 150 DM (£45).

On the whole this was a successful conference, bringing both theoretical and practical people together and the visit to the Ratskeller made it all worthwhile.

J. ASTIN

THE RHEOLOGY OF PASTES

Undoubtedly, very few types of material are met more often in daily life than pastes. We probably encounter them most frequently in food. Many pharmaceutical and cosmetic products are also sold in paste form. In the building industry a variety of pastes are used including the traditional cements, mortars and concretes in addition to the numerous modern adhesive compositions. This list is by no means complete.

One reason why the widespread use of pastes fails to be matched by a corresponding amount of rheological research is their complex nature. They are usually made up from several components often having a distribution of sizes and of various shapes. These are not easy to describe theoretically and their mechanical behaviour is difficult to imitate by model structures. Thus they are not attractive materials for academic research.

Most industrial research on pastes is directed towards specific products, processes or uses rather than to understanding basic rheological principles. As a result, accounts of paste rheology tend to be found in journals and books relating to individual industries. Some of these which I use are given in the list of references. This is *not*, however, intended to be a full survey of the available literature. Work on soil mechanics¹ is included because of the sophisticated experimental techniques developed to study deformations in three dimensions and also the use of Mohr failure criteria. Reiner's book² includes much work relevant to pastes including the equations for extrusion and shearing between cylinders of generalised Bingham bodies with wall effects. High in any collection of literature on pastes are the works of Scott Blair, particularly in relation to the food industry.^{3,4}

Clearly, the uses of pastes are many and—as I said at the Plymouth Conference—there is ample scope for cross-fertilisation between research in different fields.

The following account describes very briefly some of my work and that of others on ceramic pastes. It would be instructive to have more complete descriptions of other paste rheology in later issues of the Bulletin.

Part of my present work on pastes concerns the extrusion of ceramic pastes for catalyst supports and of enzymes for food processing. The purpose of the work is to elucidate the factors linking

composition, extruder output-rate and machine geometry as well as finding out how extrusion conditions influence product quality.

Thus, much of this note deals with paste extrusion.

It is convenient to consider die flow in two parts, i.e. the behaviour near the die-entry when the cross-section is decreased and flow in the die-parallel. In general, pastes exhibit Bingham flow behaviour in shear but most of those I encounter are sufficiently rigid to flow as plugs within dies of uniform bore. Deformation is restricted to a thin layer of material at or near the die wall. Resistance to flow is caused by drag at the die-wall.⁹

To measure the extrusion parameters of catalyst pastes and to form small amounts of experimental products we use a simple ram extruder in conjunction with an Instron Tester.

The ram is driven downwards at pre-set speeds and the resultant force produced on the barrel is measured with compression load cells. A variety of die shapes and sizes are used and the die entry contribution is found by extrapolating the results to zero die length. The effects of extrusion speed are analysed to separate out the different retarding forces in the die.

These forces include an "adhesive" component which is needed to initiate flow and is found by extrapolating the extrusion forces to zero rate. It is a considerable simplification if the effects of pressure are sufficiently small to be ignored. When this is not so, the pressure gradient along the die is not linear and it is then necessary to take into account the relation between the axial and radial pressures. Their ratio is not necessarily unity. (Some of the elegant experimental techniques developed recently to examine frictional behaviour during die compaction of lubricated powders may be useful to help understand the detailed pressure distribution during paste extrusion.)¹⁵

The velocity dependence of the retarding force can be linked to the viscous properties of the continuous phase. For example, when this shows shear-thinning a corresponding power law relationship is found in the flowing paste.¹⁰

Consider now the resistance to flow at the entrance to the die. Here the paste must not only change its shape but also reduce its cross-sectional area. The laws governing this process for ceramic pastes are found to be similar to those derived for wire drawing and the extrusion of metal powders.^{11,12} The resistance is directly proportional to the logarithm of the reduction ratio of the areas. The flow into the die involves considerable particle re-arrangement and advantageous dispersal of the liquid phase to produce added strength in the extrudate. Perhaps surprisingly the pressure drop at the die entry is for many ceramic materials practically independent of the extrusion rate. This probably depends on the relative magnitudes of

the forces needed to re-arrange the rigid powder particles and those needed to deform the continuous fluid phase. If the solid particles can be easily rearranged or deformed and the liquid phase is highly viscous I would expect the retarding force to be rate dependant. Certainly, when extruding enzymes which are a combination of biological cells and polymeric flocculation agents the die entry component is velocity dependant.

The form of expression which we find to be capable of describing the flow of our ceramic pastes through dies of uniform circular cross-sections is $P = 2 Y \ln D_o/D + (4L/D) (T_{ro} + kv)$

where D_o = Barrel diameter

D = Die diameter

L = Die length

v = Extrudate velocity

P = Applied pressure

and Y , T_{ro} and k are material parameters.

These three parameters are found to depend in a similar manner on the liquid content of the paste. If the gap between the solid particles is small the resistance to flow is high and conversely as the separation between the particles increase the resistance to flow falls by the expected amount.

In the traditional ceramics industry the plasticity of a paste is considered to be an important property. This has been defined as the property that enables a material to be changed in shape without rupturing and to retain that shape when the deforming force is removed or reduced below a certain value. It is thus closely linked to the Bingham Yield value and is determined by other methods as well as the ram extrusion technique already described.

Moore^{13,14} described in detail two instruments for studying clay plasticity and gave an account of clay plasticity, its technological measurement, importance and application. Laboratory instruments involve axial compression and t oscillations of cylinders. For plant use cone-indentation and penetrometer methods are more convenient because they involve no sample preparation. The depth of penetration of a cone under a standard applied load provides a direct indication of the yield properties and plasticity.

In conclusion I must again stress that this very brief account of paste rheology is influenced very much by my own interests and experience. The test methods, apparatus and interpolations developed in different fields of interest have in my opinion a wider application. Future notes in the Bulletin from other rheologists in industries making pastes may be a means of bringing this about.

J. J. BENBOW

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SELECTING PRACTICAL DERIVED S.I. UNITS:

A DILEMMA

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Attempts to reach agreement on the selection of derived S.I. units for specific applications often bog down in the dilemma of trying, on the one hand, to follow the rules of pure S.I. practice, while at the same time developing derived units that are practical and realistic. This essay makes no attempt to resolve this dilemma; it is intended only to recognise its existence and to point out the need for co-operative efforts among trade associations, standards writing organisations, and others concerned with establishing standard practices. The derived unit dilemma can be expressed as follows:

● By sticking to *pure S.I. rules* to deriving units, one can end up with conceptually absurd results.

● By *not* sticking to pure S.I. rules in deriving units, one can end up with multiple choices, potential confusion, and a lot of arguments.

The problem arises when trying to adhere to the following rules for deriving units:

● Use only one prefix in the derived unit.

● Put the prefix in the numerator.

● Select the prefix so that the numerical value of the quantity measured lies between 0.1 and 1000.

● Avoid the prefixes *centi-*, *deci-*, *deka-*, and *hecto-*, except in certain area and volume measurements.

The writers of guides to metric practice recognise the impossibility of adhering to all of these rules simultaneously. As a result, weasel words like "if convenient", "in general", "usually" and "the preferred practice" are common.

Let's take as an example the breakdown strength of wire insulation. By following the rules, the value would be megavolts per metre with a typical value of 25:

MV/m

But when was the last time you saw a wire with insulation a metre thick? Normal wire insulation thicknesses are measured in millimetres or even micrometres. Conceptually, then it makes more sense to put millimetres in the denominator:

V/mm

This would have a value of about 25,000. Since this number is out of the preferred range of numbers, perhaps the unit itself should be kilovolts per millimetre:

kV/mm

This unit has two prefixes, including one in the denominator, but it makes sense conceptually.

Measuring the impact strength of a film poses a similar problem. Following pure S.I. rules would give the unit megajoules per metre:

MJ/m

I submit, however, that if the material were a metre thick, it would no longer be a film. Since films are measured in micrometres, the unit more properly should be joules per micrometre, or perhaps centijoules per micrometre, if you can tolerate the use of a prefix that is frowned upon in technical work.

The executive subcommittee of A.S.T.M. Committee F-2 on Flexible Barrier Materials has recently published guidelines for the

S.I. conversion of units in this field.¹ Perhaps Committee F-2 will forgive me if I suggest that their proposed unit for gas transmission rate, femtometres per pascal-second, is a departure from reality:

$$\text{fm}/\text{Pa} \cdot \text{s}$$

The original formula clearly represented the number of cubic centimetres of gas that would pass through one square metre of a "flexible barrier" per day as a function of the pressure:

$$\text{cm}^3/\text{m}^2 \cdot \text{atm} \cdot \text{d}$$

Centi-, atmosphere, and day are frowned upon, however.

Determining how the femtometre resulted from "purifying" this formula makes an interesting exercise. The cubic centimetre was replaced by its equivalent in cubic metres. The atmosphere and the day were both replaced by the much smaller units pascal and second, respectively. These operations result in the following approximate values:

$$10^{-6} \text{ m}^3/\text{m}^2 \cdot (10^5) \text{ Pa} \cdot (10^5) \text{ s}$$

Because the next operations are purely mathematical in nature, they result in removing the formula from the realm of reality. The metre cubed (volume) is divided by the metre squared (area) to result in the metre (linear) in the numerator. The powers of ten are combined in the numerator and converted to the prefix *femto* with the conversion factor of 0.1143. This is an interesting exercise in pure S.I. form, but in my judgment it bears no relation to the physical phenomenon it is supposed to measure.

Now let us turn to the field of fibre and textile technology. Here again, as with films and coatings, the physical objects are measured in micrometre thicknesses. Thus, it is again absurd to express a property of a filament as a function of its thickness in terms of "something" per metre.

At the present time the linear density of a filament or yarn is measured in terms of denier, which is defined as the weight (mass) in grams of 9,000 metres of yarn. Since 9,000 is not a coherent unit, the linear density will instead be measured in terms of the tex unit, the mass in grams of 1,000 metres of yarn:

$$\text{g}/\text{km}$$

This formula, however, has a prefix in the denominator. Thus the Textile Research Institute feels that the proper unit would be milligrams per metre²:

$$\text{mg}/\text{m}$$

The prefix has been moved to the numerator, but the resulting formula in no way reflects the actual measurement of the tex of a yarn. In practice one winds up 100 or 1,000 metres of the yarn and determines its mass directly.

The international standard³ goes even further in disguising the meaning of tex by defining it in terms of S.I. basic units:

$$10^{-6} \text{ kg/m}$$

I confess that I had to spend quite some time trying to determine what this meant when I first saw it. Really now, what's wrong with grams per kilometre?

The denier unit was a convenient one, in that denier-per-filament values ranged from around 2 to perhaps 20. Textile multifilament yarns would have denier values under 100, and denier numbers larger than this clearly indicated values for tow or very heavy yarns. To get the same convenient range of numbers for these types of yarns, the decitex is now being used. There are some who argue against adopting the unit, however, since the prefix *deci-* is to be avoided in pure S.I. usage.

These are some of the factors contributing to the existence of an unwieldy multiplicity of units for measuring yarn tenacity that have been recommended by responsible authorities.^{2,4,5} They are listed, along with the conversion factors from the present tenacity measurement, grams (force) per denier, in Table 1. The proponents of each unit argue variously that they follow pure S.I. rules, give a convenient range of numbers, or best represent conceptually the actual measurements that are being made.

From these examples one may conclude that there may be sound technological reasons for deviating from pure S.I. rules in the selection of derived units, in order for the units to make sense conceptually. In such cases, however, it is imperative that agreement be reached within the industry on the unit to be selected before multiple derived units for the same application come into general use.

TABLE 1—Yarn tenacity measurements

Unit	Conversion Factor from Grams per Denier
mN/tex	88.3
cN/tex	8.83
mN/dtex	8.83
cN/dtex	0.883
dN/tex	0.883
N/tex	0.0883
kN·m/kg	88.3
MN·m/kg	0.0883

REFERENCES

- 1 "Guidelines for S.I. Conversion of Units in the Field of Flexible Barrier Materials" in *1978 Annual Book of A.S.T.M. Standards*, Part 21, American Society for Testing and Materials, Philadelphia, 1978, p. 389.
- 2 "Information Regarding S.I. Units", *Textile Research Journal*, Vol. 47, No. 8, 1977, pp. 568-574.
- 3 "S.I. units and recommendations for the use of their multiples and of certain other units", I.S.O. 1000-1973(E), International Organization for Standardization, Geneva, 1973, p. 6.
- 4 "Suggested S.I. Units for Textiles", A.S.T.M. Committee D-13 on Textiles, American Society for Testing and Materials, Philadelphia, 1974.
- 5 "Metric Memo No. 2", American Textile Manufacturers Institute, Inc., Charlotte, N.C., n.d.

JAMES G. VAN OOT

CALL FOR PAPERS

THE ANNUAL CONFERENCE OF GROUPE FRANCAIS DE RHEOLOGIE

A conference on The Rheology of Thin Layers will be held in Paris on 6th December, 1979.

If you wish to submit a paper please contact: R. Courtel, 1 place Aristide Briand, 92190 Bellevue, France; or M. Joly, Lab. de Biophysique, 91 bd. de l'Hopital, 75013 Paris, France.

Suggested topics are:

- (i) the mechanical and thermodynamic properties of superficial phases and thin layers;
- (ii) the structure and rheology of films on liquid surfaces;
- (iii) parietal flow in fluid mechanics and biorheology;
- (iv) the structure and rheology of thin layers on solid surfaces;
- (v) interfacial problems in contacting media (lubrication, intergranular slip).

Papers are normally presented in French.

FIFTH INTERNATIONAL CONFERENCE ON FRACTURE

ICF 5

in CANNES, FRANCE

29th MARCH-3rd APRIL, 1981

After Sendai, Brighton, München, Waterloo, the next International Conference on Fracture "ICF5" will be held in Cannes, France from 29th March to 3rd April, 1981. It is sponsored by the International Congress on Fracture and organised by the French Society of Metallurgy (S.F.M.).

MAIN TOPICS

1. Practical applications of fracture mechanics
2. Crack tip singularity computations
3. Physical fracture processes; structural aspects
4. Elastoplastic fracture mechanics
5. Fatigue
6. Influence of environment on fracture toughness
7. Testing techniques

DEADLINE for the submission of abstracts: September 1979.

EXHIBITION of apparatus associated with fracture during the conference inside the conference Palace.

FOR FURTHER INFORMATIONS and detailed announcement write to General Secretary of the conference:

Jacques POIRIER-CEA-DMECN

BPn° 2

91190—GIF-SUR-YVETTE—FRANCE

FUTURE MEETINGS

APPLIED RHEOLOGY

Provisional programme for the Conference on Applied Rheology to be held at the University College of Wales, Aberystwyth, 11th-14th September, 1979.

Wednesday, 12th September

9.00- 9.30 Opening address by the President, W. M. Jones
"Flow through porous materials"

- 9.30-10.00 "Foam as an enhanced oil recovery agent"
by C. N. Nutt and R. Burley
- 10.00-10.30 "Fluid behaviour at solid/liquid/air surfaces"
by R. Burley
- 11.00-11.30 "Complexities in the flow of 2-phase systems through
porous media"
by R. A. Dawe
- 11.30-12.00 "The influence of viscous, inertia, and normal stress
effects on the load bearing capacity of a squeeze film
of liquid"
by D. R. Oliver
- 12.00-12.30 "The rheology of soap"
by H. A. Barnes and B. Edmondson
- 14.00-14.30 "The use of vibration for compaction of cement pastes
and concretes"
by C. R. Dimond and G. H. Tattersall
- 14.30-15.00 "The effect of large particles on the onset of turbulence
in a mixing process"
by C. R. Dimond and G. H. Tattersall
- 15.00-15.30
by J. M. Davies
- 16.00-16.30 "Minimum running thickness of a polyethylene film in
biaxial extensional flow"
by F. N. Cogswell and M. S. Swerdlow
- 17.00 Annual General Meeting of the Society

Thursday, 13th September

- 9.00- 9.30 "Numerical solution of unsteady convective diffusion
with chemical reaction in time dependent flows with
application to mass transfer in pulsatile blood flow"
by G. Akay
- 9.30-10.00 "The rheology of human saliva and the development
of a substitute secretion"
by B. J. Roberts
- 10.00-10.30 "The prediction of whole blood viscosity from simple
haematological parameters"
by R. D. Hutton
- 11.00-11.30 "Numerical solutions of rheological flows involving
abrupt changes in geometry"
by A. R. Davies
- 11.30-12.00 "Application of Laser Doppler Velocimetry to
rheological flows involving abrupt changes in
geometry"
by T. Cochrane

- 12.00-12.30 "A High-pressure, high-shear rate capillary viscometer"
by G. D. Galvin, J. F. Hutton and B. Jones
- 14.00 Trip to the Centre for Alternative Technology, Machynlleth

Friday, 14th September

- 9.00- 9.30 "The effect of die rotation on weld lines in extruded pipes"
by R. A. Worth and D. I. H. James
- 9.30-10.00
by T. E. R. Jones
- 11.00-11.30 "Weak gels"
by I. M. Van den Tempel
- 11.30-12.00 "Thermodynamics of wall slip"
by L. P. B. M. Janssen
- 12.00-12.30 "Dynamic mechanical studies on thermo-reversible ageing processes in gelatin gels"
by K. te Nijenhuis

NOTE: A poster session is planned for Thursday morning.

Also a discussion is being planned on CASE awards, with spokesmen from industry, S.R.C. and the universities.

BRITISH SOCIETY OF RHEOLOGY

CONFERENCE

on

APPLIED RHEOLOGY

11th-14th September, 1979

APPLICATION FORM

I wish to attend the meeting at Aberystwyth and enclose payment of the composite fee of £50 (plus a Conference Fee of £5 payable by non-members of the Society).

Participants' guests will be welcome at the Conference Dinner, at an extra charge of £7.50.

NAME (and title)

ADDRESS

.....

.....

.....

Conference Secretary: Mr. J. ASTIN,

Department of Applied Mathematics,
U.C.W.,
Penglais,
ABERYSTWYTH,
U.K.

PLEASE APPLY BY 14th AUGUST, 1979

THE MECHANICAL PROPERTIES OF BIOLOGICAL MATERIALS

Each year the Society for Experimental Biology runs an International Symposium. This year the subject is "The Mechanical Properties of Biological Materials". It is being organised by Dr. J. F. V. Vincent of Reading and Professor J. D. Currey of York.

Venue: Leeds University. Dates: 4th-6th September, 1979.

PROGRAMME

Tuesday, 4th September

Professor R. McN. Alexander: Welcome and introduction to the symposium

Professor J. E. Gordon: Biomechanics—the last stronghold of vitalism

Professor E. H. Andrews: Fracture

Professor B. Harris: Theory of composite materials

Professor J. D. Currey: Mechanical properties of mollusc shells

Professor N. E. Waters: The physical and mechanical properties of the human tooth

Professor J. L. Katz: The structure and biomechanics of bone

Wednesday, 5th September

Dr. G. Jeronimidis: Wood—one of nature's challenging composites

Dr. D. B. Sellen: Mechanical properties of plant cell walls

Dr. J. F. V. Vincent: What's the point of sclerotisation?

Dr. R. D. B. Fraser: Molecular structure and mechanical properties of keratins

Mr. M. Denny: Silks—their properties and functions

Dr. L. Mullins: Theories of rubber-like elasticity and the behaviour of filled rubbers

Dr. K. L. Dorrington: The theory of viscoelasticity in biomaterials

Thursday, 6th September

Dr. J. M. Gosline: The elastic properties of rubber-like proteins and highly extensible tissues

Professor R. H. Pain: The viscoelasticity of mucus—a molecular model

Professor S. A. V. Swanson: Articular cartilage

Professor E. Baer: Relationships between structural hierarchies and mechanical properties of tendon collagen

Professor S. A. Wainwright: Adaptive materials

Professor W. D. Biggs (chair): (discussion)—Evolution and design—Where do we go from here?

As organisers we have aimed to have enough theory given, for instance in the lectures by Professors Andrews and Harris, to put the biologists on the right path, while allowing plenty of discussion of real biological materials. We have also tried to span the range of biological materials and properties, from brittle mollusc shells to slime and mucus. We have tried to guide the speakers to give reviews rather than "up-to-the-minute reports from my lab.". The talks will be published in a symposium volume. There will be a poster session and entries are invited for this. This promises to be an unusual symposium which we think will interest many non-biologists. Certainly we hope that we shall have a number of polymer scientists, materials scientists, medical workers and engineers in the audience.

Booking forms will be available from

Society for Experimental Biology,
Harvest House,
62 London Road,
READING,
RG1 5AS,
U.K.

If you are interested in taking part in the poster session, contact me, Dr. J. F. V. Vincent, at

Biomechanics Group,
Department of Zoology,
Whiteknights,
READING,
RG6 2AJ,
U.K.

I shall also be glad to answer any other general queries you may have: telephone 0734-85123, ext. 7609.

J. F. V. VINCENT,

Joint Convener with J. D. Currey

**THE SOCIETY OF RHEOLOGY GOLDEN JUBILEE
(1929-79) MEETING**

BOSTON, MASSACHUSETTS

28th October-2nd November, 1979

Golden Jubilee Committee:

Mr. E. J. Tolle, Box 134, Accord, MA 02018, U.S.A.

You are cordially invited to participate in the Golden Jubilee of The Society of Rheology which will take place at the Copley Plaza

Hotel in Boston, Massachusetts, U.S.A. during the week of 28th October to 2nd November, 1979. To celebrate this 50th Anniversary of the founding of the science of rheology and The Society of Rheology, a meeting is planned which we hope will include all aspects of rheology.

If any member is interested in group travel arrangements please contact Secretary, Dr. C. J. S. Petrie, as soon as possible.

RESEARCH STUDENTSHIPS

Research studentships are available in the Department of Building Science of the University of Sheffield for research in the rheology of fresh concrete and cement pastes.

One student will be supported by an S.R.C. CASE award (£2,555 p.a.) and will work on the effect of cement properties on the workability of concrete.

Other projects are concerned with the further development of a method of workability measurement devised in the Department and the application of that method to problems of industrial and scientific interest. In addition studies are carried out on the rheology of cement pastes.

Further information may be obtained from:

Dr. G. H. Tattersall
Department of Building Science
University of Sheffield
S10 2TN

VISITING RHEOLOGIST—PROFESSOR K. ITO

As reported at the last Annual General Meeting (see Bulletin 21, No. 4, p. 52) we accord the status of acting membership to visiting rheologists in good standing with their own Societies. It seemed reasonable to Council that we should advertise the presence of such visitors in Britain, so that members may have the opportunity of arranging to meet them if they wish.

Professor K. Ito, of the Department of Mechanical Engineering of Hosei University, Tokyo, Japan, is visiting Dr. Petrie at the Department of Engineering Mathematics, University of Newcastle upon Tyne, from March to October this year. His programme includes visits to a number of universities and industrial research groups, as well as starting on a research project connected with blow moulding. Professor Ito's interests include extrusion die design, cold and warm processing (forming from sheet) of polymers and composites, viscoelastic behaviour of amorphous polymer solids and

residual stress and strain in injection-moulded plastic products. He is a member of the Japanese Society of Rheology and of the Society of Rheology.

C. J. S. PETRIE

NOTICES

PROCEEDINGS OF THE I.U.T.A.M. SYMPOSIUM ON NON-NEWTONIAN FLUID MECHANICS

The Proceedings of the above Symposium, held in Louvain-la-Neuve, Belgium on 28th August-1st September, 1978 are published as a special volume of the Journal of Non-Newtonian Fluid Mechanics, Vol. 5 (April 1979). This may be purchased from Elsevier at the normal price of Dfl. 254. Members of the British Society of Rheology, however, may purchase copies at the special price of £25 (including postage and packing) if they order quickly.

Orders should be sent to:

Mr. A. W. van der Avoird
Elsevier Scientific Publishing Company
Jan van Galenstraat 335
P.O. Box 330
1000 AH Amsterdam
The Netherlands

This special price can only be offered if orders are *accompanied by a cheque* payable to Elsevier Scientific Publishing Company. In all other cases, e.g. when an invoice is required or if payment is made by bank transfer, the normal price has to be charged. Your cheque should reach Mr. van der Avoird within three months after publication of this Bulletin.

The Proceedings contain xiv + 513 pages.

PROCEEDINGS OF THE VIIth CONGRESS ON RHEOLOGY

The Proceedings of this congress at Gothenburg 1976 is now on sale at the reduced price of U.S. \$10 compared to the usual price of \$64. A cheque payable to the Swedish Society of Rheology should be enclosed with an order and sent to:

Swedish Society of Rheology
c/o Dr. C. Klason
Pl 2201, S-44100
Alingsås
Sweden

APPLICATIONS FOR MEMBERSHIP—APRIL 1979

Bruno Celard, M.Sc. p,et,a,D,F,K.	Centre de Recherches, Esso, 76130 Mont-saint-Aignan, France.
Dr. Ernst Eklund Dan, Ph.D. p,et,a,E,G.	Institutionen for traforadling/ Åbo Akademi Porthansgatan 3, SF-20500 Turku 50, Finland.
David V. Greenwood, B.Sc. p,et,a,G,H.	I.C.I. Corporate Lab., P.O. Box 11, The Heath, Runcorn, Cheshire.
Andrzej B. Jarzebsi, D.Sc., M.Sc. et,sa	Schools of Chem. Engineering, University of Bradford, Bradford, BD7 1DP.
Michael P. Hardman, B.Sc. p,e,a,B,K.	Chemical Building Products Ltd., Cleveland Road, Hemel Hempstead.
Dr. Nigel Heywood, Ph.D., M.Sc., B.Sc. f,et,a,F,G,H,J.	Warren Spring Lab., P.O. Box 20, Gunnels Wood Road, Stevenage.
Yerzy Kramarz, Ph.D. p,et,sa,I,J.	Politechnika Krakowska, Ul. Warszawska 24, 31-155 Krakow, Poland.
Robert Wilson Lambe, M.Sc., B.Sc., Ph.D. f,et,sa,D,G,I,K.	Cement & Concrete Association, Materials Research Dept., Wexham Springs, Slough SL3 6PL.
Keith E. Middleton, Ph.D. p,et,sa,G,H.	I.C.I. Organics Div., Earls Road, Grangemouth, Stirlingshire.
Graham O'Brien, B.Sc. et,sa,B,C,D,G,H,J,L.	William Curtis House, Lenten Street, Alton, Hants.
Muhammad Shahidullah, Ph.D., M.Sc., B.Sc. f,et,sa,D,J,M.	Dept. Chemical Engineering, Birmingham University, Birmingham 15.
Joseph M. Starita, Ph.D. f,e,sa,B,M.	Rheometrics, GmbH, Arabella Center, Lyoner Strasse 44-48, D-6000 Frankfurt 71, West Germany.
Jan M. Strand, M.Sc. f,et,sa,E,F,G,D.	Institutionen for traforadling/abo Akademi Porthansgatan 3, SF-20500 Turku 50, Finland.

RESIGNATIONS

G. W. Hallworth.
R. N. Ruffell.
R. H. Foster.

NEWS OF MEMBERS

Dr. Janssen's address is now:

Dr. L. P. B. M. Janssen, (Ir.)
Technische Hogeschool Delft
Prins Bernhardlaan 6
2628 BW Delft, N

DIARY

1979

4th-6th September. "Mechanical Properties of Biological Materials." Leeds.

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

28th October-2nd November. U.S. Golden Jubilee Meeting—Boston.

6th December. "Rheology of Thin Layers." Paris.