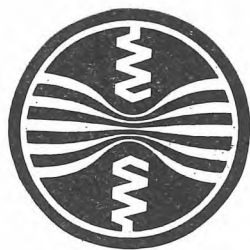


BULLETIN



BRITISH SOCIETY OF RHEOLOGY

1969, No. 1, Vol. 12

Hon. Editor:

JOHN HARRIS,
Schools of Chemical Engineering,
The University,
Bradford,
Yorks. U.K.

FORWORD

The last edition of the Bulletin (No. 4, 1968) carried a very interesting and informative description of the early history of rheology by H. Markovitz, covering the events from the time of Hook and Newton forward, up to the founding of the Society of Rheology in 1929.

Apart from the historical development described, which shows amongst other things that there has been little improvement in the precision of experiments since the early days, the article proffered a very much more restricted definition of Rheology than the usual one; "the science of deformation and flow" (of matter), whereas the suggestion in the article was: "rheology—a branch of mechanics—is the study of those properties of materials which determine their response to mechanical force."

The latter definition is clearly well on the way to creating an identifiable branch of knowledge and is quite similar in content to that given by the present Editor at the B.S.R. Exeter meeting in September, 1964 (see the Bulletin 1965, No. 1, p. 14).

At that time, the definition proposed: "rheology is the study of the relationships between stress, strain and time" was countered with the dictum "rheology *includes* continuum mechanics" (Pearson). There is evidently now opinion on both sides of the Atlantic that sweeping assertions about the parts of knowledge which are included by some under the heading of Rheology, only partly resembles what people actually do who call themselves rheologists, and what is included for example in Rheology Abstracts and the Survey of Rheological Research.

Under the circumstances there is much to be said for a restricted definition, however, one of these properties of materials which determines their response to mechanical force is *mass*, and it seems that a restricted definition will have to be cast in other terms than these. Members of the Society are invited to submit definitions of Rheology so that some idea of current opinion on this matter can be formed.

Members are also reminded that technical papers can now be accepted for publication in the Bulletin subject to the usual refereeing process. Authors will receive 25 free copies of their articles.

CONTENTS					Page
Foreword	...	...	...	...	1
Officers and Council	...	...	...	...	3
Victorian Branch 1968-69 Committee	...	...	...	...	3
Post-Extrusion Recovery of Viscoelastic Materials (W. C. MacSporran)				...	5
Useful Formulae and Techniques for the Weissenberg Rheogoniometer (J. Harris and W. L. Wilkinson)	...	...	...	...	9
Computer Program Catalogue (Notes)	...	...	...	...	20
Computer Program Catalogue (Form)	...	...	...	...	22
Project Reports	...	...	...	...	23
News from France (D. W. Hadley)	...	...	...	...	23
Impressions of the 5th International Congress on Rheology (J. F. Hutton)				...	30
Personal Notes	...	...	...	...	34
Reclassification of Members Interests	...	...	...	...	34
Titles of Papers Presented to the 39th Annual Meeting of the Society of Rheology	...	...	...	...	34
Diary	...	...	...	...	36
Recent Elections	...	...	...	...	36

COUNCIL

Officers

President: DR. L. GRUNBERG, National Engineering Laboratory, East Kilbride, Glasgow.

Hon. Secretary: DR. B. S. NEUMANN, Laport Industries Limited, Redhill, Surrey.

Hon. Treasurer: MR. R. J. COLE, Paint Research Station, Teddington, Middlesex.

Membership Secretary: DR. K. WALTERS, Department of Applied Mathematics, University College, Aberystwyth.

Abstracts Editor: MR. B. WARBURTON, School of Pharmacy, Brunswick Square, London.

Bulletin Editor: DR. J. HARRIS, Schools of Chemical Engineering, The University, Bradford.

Ordinary Members

DR. K. M. BEAZLEY, DR. D. W. HADLEY, MR. A. T. J. HAYWARD, DR. J. R. A. PEARSON, DR. G. H. TATTESALL, MR. R. W. WHORLOW.

Research Committee

DR. J. R. A. PEARSON (Chairman), DR. J. P. BERRY (Secretary), DR. M. F. CULPIN, MR. A. EVANS, MR. A. T. J. HAYWARD, MR. P. LAMB, Professor F. J. RAFFLE, MR. B. WARBURTON.

1968-69 COMMITTEE, VICTORIA BRANCH (AUST.)

President: MR. K. R. HALL, (C.S.I.R.O., Division of Chemical Engineering).

Secretary: DR. D. V. BOGER (Monash University, Department of Chemical Engineering).

Treasurer: MR. K. G. MARTIN (C.S.I.R.O., Division of Building Research).

Committee: MR. B. C. BROWN (Nylex Corporation), MR. D. H. MORTON, (A.P.M.), DR. E. J. DICKENSON (Australian Road Research Board)

POST-EXTRUSION RECOVERY OF VISCOELASTIC MATERIALS

By W. C. MacSporran

Postgraduate School of Studies in Chemical Engineering, University of Bradford, Bradford 7, Yorks.

Recently Rigbi¹ has resurrected the question of whether the post-extrusion swelling of a viscoelastic material should be called the Barus^{2,3} or Merrington⁴ effect. He restates the conclusion of Truesdell⁵ that the phenomenon which Barus observed was not the same as that of Merrington. He, therefore, argues that the phenomenon should be called the Merrington effect. Truesdell also credits Merrington with being the first to observe this phenomenon. However, a more careful search of the literature reveals that the post-extrusion swelling effect was well known long before Merrington's work was published. It is also apparent from the literature that the phenomenon reported by Barus is the same as that observed by the later workers, including Merrington.

Changes in shape of a material emerging from a tube appear to have been first commented upon by Barus in 1893 while extruding marine glue. The swelling effect was again reported as being widely observed in the rubber industry during the 1920's and '30's. De Visser,⁶ in 1926, reported that he had observed a swelling effect while calendering sheets of unvulcanised rubber. In 1933 Dillon and Johnston,⁷ while developing an extrusion plastometer operating at rates of shear comparable with those existing in rubber tubing machines, observed post-extrusion recovery of technical mixtures of rubber. In 1937 Houwink⁸ emphasised the importance of the elastic properties of materials during extrusion. He gave as an example the tubing process in the rubber industry and referred to the post-extrusion recovery as the Barus effect. Observations of the Barus effect, about this time, were not restricted solely to the rubber industry. In 1936 Halton and Scott Blair⁹ reported that they had observed a swelling effect while extruding flour dough. Further observations of the swelling effect were not reported until the 1940's. In 1943 Merrington reported that he had observed extrusion swelling of rubber solutions and mineral oils gelled with metal soaps and suggested that the swelling should give a measure of the elasticity of the material. He referred to the swelling as the Barus phenomenon and quoted the original paper (ref. 2). In 1950 Ganmer, Nissan and Wood¹⁰ reported that they had independently observed the swelling effect in hydrocarbon-soap gels between 1942 and 1946. Their work was carried out while developing materials for flame throwers and was not published until official secrets restrictions were relaxed at the end of World War II. About this time the rapidly growing polymer

industry also gave rise to reports of the Barus phenomenon. In 1948 Spencer and Dillon¹¹ presented swelling data for molten polystyrene and suggested a possible explanation. It is significant that when Nason,¹² in 1945, reported on extrudate irregularities observed while extruding molten polyethylene he made no reference to swelling. Perhaps the swelling effect was too well known to merit comment.

While it is recognised that the above review may be incomplete, it is sufficient to point out that Merrington was by no means the first to observe the post-extrusion swelling effect nor was he in fact the first to realise its significance as a measure of the elasticity of the material.

That the post-extrusion recovery effects observed by the above workers were all of the same kind is obvious from closer inspection. Barus³ observed the changes of shape shown in Fig. 1. A cylinder of the glue which had extruded, Fig. 1(a), was cut off with a sharp knife at the tube exit plane (Section AA). Soon after cutting a conical protuberance began to appear on the cut face and after 24 hours the cylinder had passed into the shape shown in Fig. 1(b). After a much longer period of time the cylinder assumed the shape shown in Fig. 1(c). It should be noted that there is a small increase in diameter of the cylinder, which was initially of the same diameter as the tube D). Barus did not comment upon this diameter change although it is clearly indicated in his original diagram. The post-extrusion

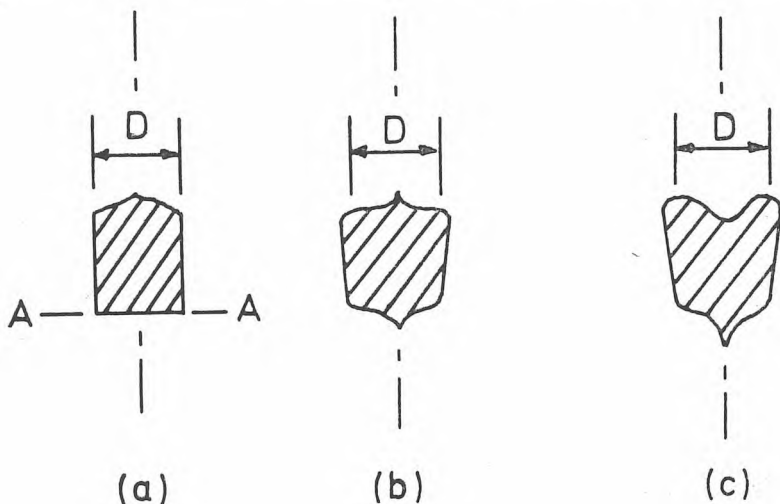


FIG.1. BARUS⁽³⁾ EFFECT.

recovery observed in the rubber tubing process was described by Houwink.⁸ The extruded rubber has a diameter larger than that of the die as shown in Fig. 2(a). A piece of the rubber (dough), cut off immediately after tubing, assumes the form shown in Fig. 2(b). The swelling effect reported by Merrington⁴ was essentially the same as that shown in Fig. 2(a).

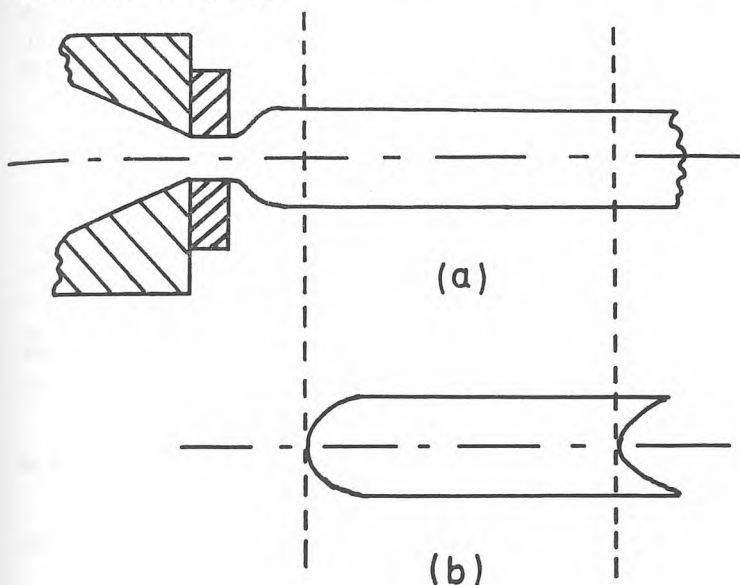


FIG.2. RUBBER TUBING (HOUWINK⁽⁸⁾).

The above three workers appear to have reported the same phenomenon. There are, however, subtle differences of behaviour which may be attributed to the nature of the materials used. The reports of Barus and Houwink refer to materials which are more solid than liquid whereas that of Merrington refers to materials which are essentially liquids. The difference of behaviour observed in the three cases may be related to the relaxation times of the materials: The marine glue has a relaxation time which may be measured in days; the rubber has a relaxation time of several seconds (possibly minutes); and, Merrington's solutions and gels have relaxation times which are small fractions of a second.

In conclusion, therefore, the post-extrusion recovery effects reported by the various authors all have their origin in the elasticity of the

materials used. Subtle differences of behaviour are almost certainly due to the relative magnitudes of their relaxation times. On this basis the phenomenon should be attributed to Barus and not to Merrington. In any case, the swelling effect appears to have been known throughout the rubber and polymer industries long before Merrington published his celebrated photograph. It seems likely that the importance placed on his work derives from its fortunate coincidence with the vast upsurge of interest in and understanding of the behaviour of viscoelastic materials brought about by the wartime studies of Weissenberg, Garner, Reiner and their co-workers.

Literature Cited

- ¹ Rigbi, Z.; *Bull. Brit. Soc. Rheol.*, **4**: 23 (1968).
- ² Barus, C.; *Proc. Amer. Acad. Arts Sci., Series 2*, **19** (No. 27): 13 (1893).
- ³ Barus, C.; *Amer. J. Sci., Series 3*, **45** (No. 148): 87 (1893).
- ⁴ Merrington, A. C.; *Nature*, **152**: 663 (1943).
- ⁵ Truesdell, C. & W. Noll; "The Nonlinear Field Theories of Mechanics" in *Hanbuch der Physik III/3*. S. Fleugge (ed). Springer Verlag. 1965. p. 458.
- ⁶ de Visser, W.; "Calender Effect and Shrinkage Effect of Unvulcanised Rubber." London. 1926.
- ⁷ Dillon, J. C. & N. Johnston; *Physics (J. Appl. Phys.)*, **4**: 225 (1933).
- ⁸ Houwink, R. & W. G. Burgers; "Elasticity, Plasticity and the Structure of Matter." Cambridge. 1937. p. 203.
- ⁹ Halton, P. & G. W. Scott Blair; *J. Phys. Chem.*, **40**: 561 (1936).
- ¹⁰ Garner, F. H., A. H. Nissan & G. F. Wood; *Phil. Trans. Roy. Soc.*, **A243**: 37 (1950).
- ¹¹ Spencer, R. S. & R. E. Dillon; *J. Colloid Sci.*, **3**: 163 (1948).
- ¹² Nason, H. K.; *J. Appl. Phys.*, **16**: 338 (1945).

USEFUL FORMULAE AND TECHNIQUES FOR THE WEISSENBERG RHEOGONIOMETER

By J. Harris and W. L. Wilkinson.

Postgraduate School of Chemical Engineering.

The University, Bradford 7, U.K.

Summary

The technique of instrument calibration using a Solartron Digital Transfer Function Analyser is described. Formulae are presented for the analysis of frequency-response experiments, these formulae avoid the unnecessary complexity of some treatments but are not restricted as are those in the rheogoniometer Instruction Manual.

In the four Appendices there are tabulated constants for various geometries, a description of two schemes for treating data, a method of extending the frequency range of the DTFA, and finally the advantage of checking for non-linearity using the DTFA over the conventional method.

Useful Formulae and Techniques for the Weissenberg Rheogoniometer

1. The Rheogoniometer

The Weissenberg rheogoniometer is designed on the principle of imposing a known deformation pattern on a material sample, either

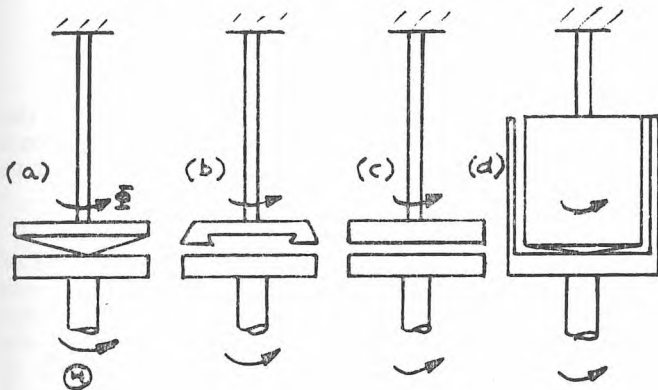


FIG.1 TYPICAL SHEARING GEOMETRIES
(a) CONE & PLATE (b) RING & PLATE
(c) PARALLEL PLATE
(d) CONCENTRIC CYLINDER.

solid or liquid, and measuring the resulting forces. Both steady shearing and *low* frequency oscillatory shearing motion can be employed.

The material to be tested is usually, although not always, confined between rigid boundaries of various geometries such as the concentric cylinder, parallel plate, cone and plate and ring and plate. The Instruction Manual¹¹ issued with the rheogoniometer treats the first three of these geometries in a simplified way, but not the ring and plate, which is of more recent origin.³ These geometries are illustrate in outline in figure 1.

The two main types of test which may be carried out, namely steady shearing and oscillatory shearing, require rather different instrumentation and consequently different calibration.

Block diagrams of the two types of experiment are shown in figures 2a, b. Ignoring for the moment normal (axial) force measurement, which is the same in principle as torque measurement, but in practice much less reliable, steady shearing calls only for an electrical signal pick-up from the top platen which is fed through a transducer meter, this may be either read directly as an analogue or preferably in digital form through a digital voltmeter.

In oscillatory testing, electrical analogue signals are required from both the bottom and top platens. By far the most convenient and efficient way of handling the information is to pass both signals to a Solartron Digital¹² or Analogue^{1,2} Transfer Function Analyser after they have passed through the transducer meters.

2. Calibration

(i) Steady Shearing

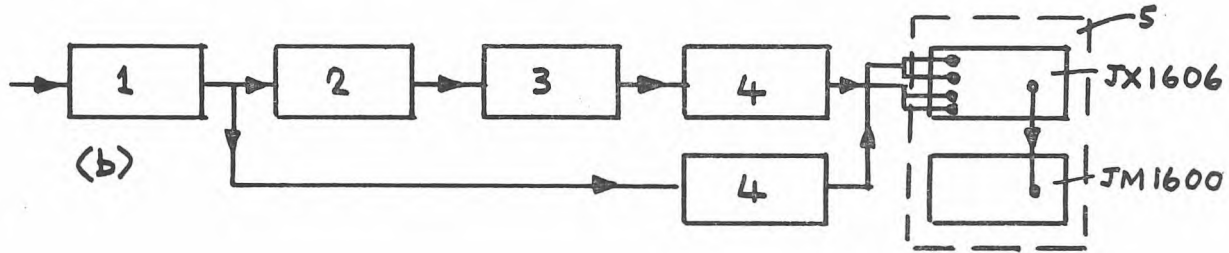
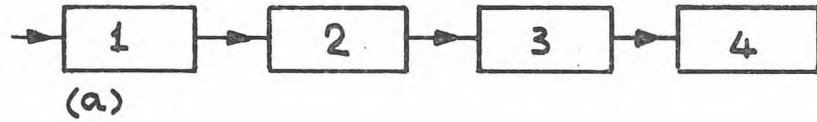
The rheogoniometer Instruction Manual¹¹ describes how, with the aid of a special micrometer, the transducers top and bottom platens) can be calibrated. It is again preferable to use a digital voltmeter to read the transducer meter.

(ii) Oscillatory Shearing

It may be seen from the diagram figure 2b that there is a total of five items, including the digitized transfer function analyser, which can phase shift and attenuate the signals, in other words there are five transfer functions involved and out of these that relating to the material itself is the only one of ultimate interest. The method of resolving the problem of isolating the material transfer function is outlined below.

Checking the DTFA

By taking a common signal to both reference and channel 1 terminals on the DTFA, say from the lower platen transducer, and checking over the frequency range of interest, see figure 3. Over the frequency range of interest the DTFA appears to have a transfer function of unity and can therefore be eliminated from consideration.



11

FIG. 2 BLOCK DIAGRAMS FOR (a) STEADY SHEARING
(b) OSCILLATORY SHEARING.

KEY: 1. LOWER PLATEN 2. TEST MATERIAL
3. UPPER PLATEN ASSY. 4. TRANSDUCER
METER. 5. DIGITAL TRANSFER FUNCTION ANALYSER.

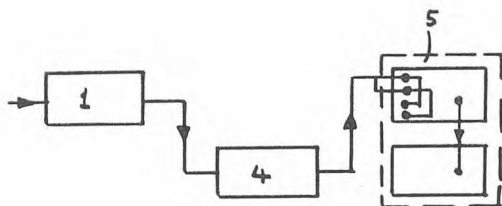


FIG.3 CHECKING THE D.T.F.A.
SEE FIG.2 FOR KEY.

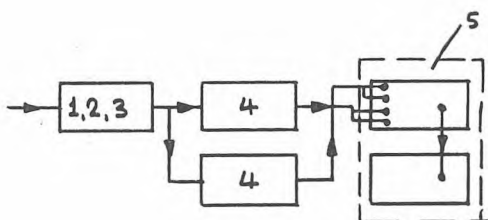


FIG.4. CHECKING THE TRANSDUCER
METERS.
SEE FIG.2 FOR KEY.

Checking the Transducer Meters

The effect of the material can be eliminated by clamping the top and bottom platens together and thereby introducing an effectively infinitely rigid material and since the top platen is forced to follow the motion of the bottom platen exactly. Hence the only two transfer functions remaining in this situation are those of the two transducer meters, see figure 4.

The sort of output obtained from both transducer meters when the amplitude of motion of the platens remains constant but the frequency is varied as shown in figures 5 and 6.

Since the attenuation of the two meters is not identical it would be inaccurate to measure the rigidity modulus by the method recommended in the Instruction Manual, namely, by calculating the ratio of the meter outputs and multiplying by an instrument constant.¹¹ (Section D2.2.)

WEISSENBERG RHEOGONIOMETER.

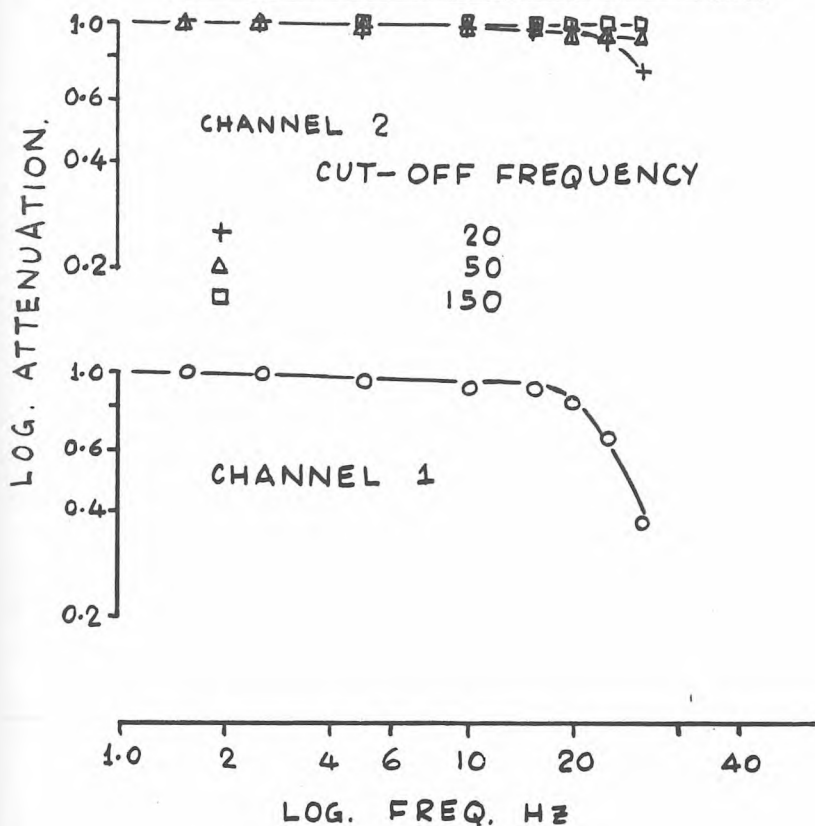


FIG. 5 LOG. ATTENUATION AGAINST LOG. FREQUENCY.

Since it is not possible to construct a reliable analytic expression for the transfer function of the transducer meter the best that can be done is to construct a table of correction co-efficients and phase additions to allow for the effect of the meters.

The range of frequencies can be extended by mounting the transducers in a jig on an electro-mechanical vibrator (Pye-Ling for example). The maximum value of frequency acceptable to by the DTFA is 159.9 Hz.

WEISSENBERG RHEOGONIOMETER.

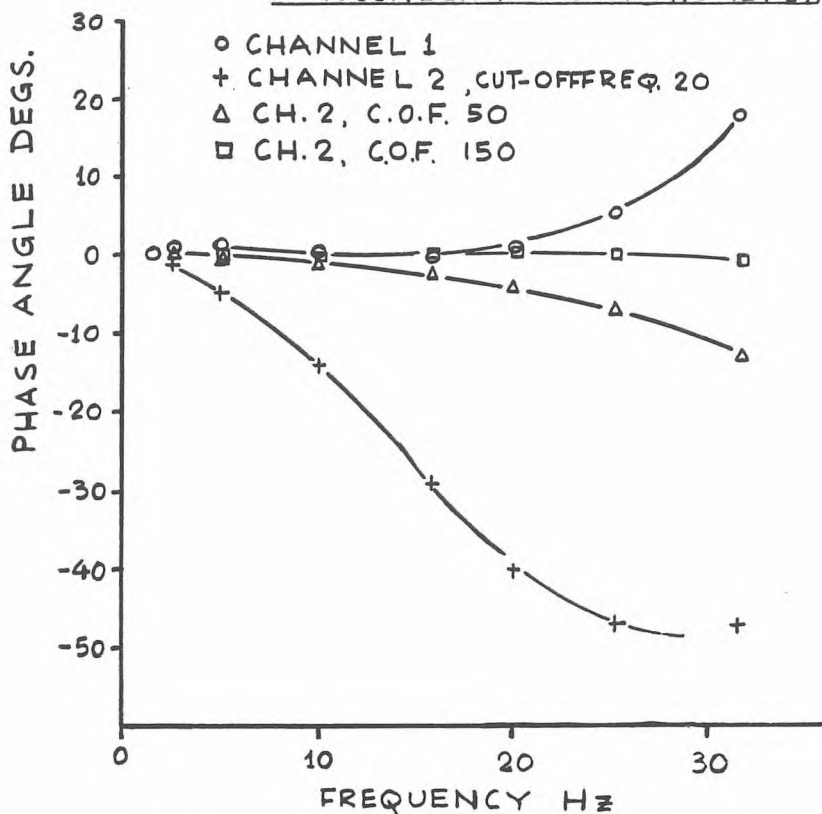


FIG. 6 PHASE v FREQUENCY RESPONSE

3. Formulae for Oscillatory Testing

(i) The Viscosity

From an examination of the current literature^{7,8,9,10} providing formulae for low-frequency testing one might obtain the impression that the choice of formulae is between rather complicated types incorporating fluid inertia which result in solutions in complex Bessel functions or the approximate forms in the rheogoniometer Instruction Manual which are not easy to read and are in any case correct only for upper platen motion which are much smaller than the lower.

By suitable arrangement the effects of inertia of the material may be reduced to negligibly small proportions. This restricts motions to

those in which (i) the length of the shear wave is much larger than the sample thickness perpendicular to the shear planes and (ii) secondary flows due to centrifugal effects are small.⁵

The above effects may be designed out of the system by using the parallel plate or ring and plate for linear response or the ring and plate for non-linear response. A narrow gap between the working surfaces will avoid the necessity of considering inertia effects in the rheogoniometer.

The formulae for the real and imaginary parts of the complex viscosity (μ^+)⁵

$$\mu^+ = \mu' - i\mu''$$

are

$$\mu' = \frac{B(K - I\omega^2)\Theta\Phi''}{\omega(\Theta^2 - 2\Theta\Phi' + \Phi^2)} \quad (1)$$

$$\mu'' = \frac{B(K - I\omega^2)(\Theta\Phi' - \Phi^2)}{\omega(\Theta^2 - 2\Theta\Phi' + \Phi^2)} \quad (2)$$

when B is a real instrument constant (see Appendix for explicit forms).

These expressions are *valid for all frequencies*. Well above the resonant, frequency products of the upper frequency motion

$$\Phi^+ = \Phi' + i\Phi''$$

are negligible and first approximations to the real and imaginary parts of the viscosity are,⁵

$$\hat{\mu}' = \frac{B(K - I\omega^2)\Phi''}{\omega(\Theta - 2\Phi')} \quad (3)$$

$$\hat{\mu}'' = \frac{B(K - I\omega^2)\Phi'}{\omega(\Theta - 2\Phi')} \quad (4)$$

If the oscillatory frequency is very much less than the natural frequency of the torsion head, i.e. $\omega \ll 2\pi(K/I)^{1/2}$ further simplification is possible, then,⁵

$$\hat{\mu}' = \frac{BK\Phi''}{\omega\Theta} \quad (5)$$

$$\hat{\mu}'' = \frac{BK\Phi'}{\omega\Theta} \quad (6)$$

The low shear rate Newtonian viscosity is given by,⁵

$$\mu = \lim_{\omega \rightarrow 0} \frac{BK\Phi}{\omega\Theta} \quad (7)$$

The formulae in the Instruction Manual¹¹ (R.18) (K.W. 1-15) and (K.W. 1.16) in section D.2.2 are similar to (3) and (4) above but neglect the $2\Phi'$ term in the denominators.

These successive approximations to the real and imaginary parts of the complex viscosity given above are comparatively simple and easy to programme for a digital computer. The equations (1) and (2) are valid both remote from and in the region of the resonant frequency of the torsion head and yet avoid the unwieldy complex functions present in some expressions.^{7,8}

It *may* be required to interpret the viscosity in terms of a relaxation spectrum.⁶ On the other hand the viscosity as a function of frequency may be perfectly adequate.

(ii) The Shear Strain

To correspond with the frequency band width of viscosities (1) and (2) there is need for a complimentary shear strain expression to replace that given in the Instruction Manual (R.18) equation (D.25), section D.2.2.

The maximum value of the strain is,

$$\gamma_{\max} = \frac{1}{A} (\Theta^2 + \Phi^2 - 2\Theta\Phi \cos \tan^{-1} \frac{\Phi''}{\Phi'})^{\frac{1}{2}} \quad (8)$$

The variation of $\gamma_{\max}$ as the frequency is increase from zero is shown in figure 7. At an oscillation frequency equal to the natural frequency of the torision head, $\omega_n (= 2\pi (K/I)^{\frac{1}{2}})$.

the upper and lower platens are in phase and have the same amplitude for both Newtonian and linear non-Newtonian materials. Hence at this frequency the strain amplitude is zero for these materials.

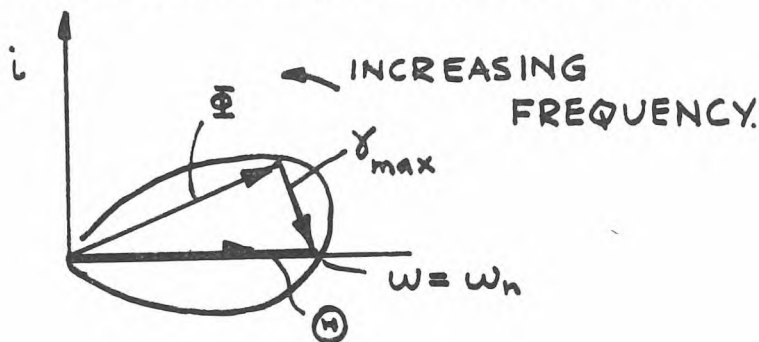


FIG. 7 PHASE DIAGRAM RELATING PLATEN AMPLITUDES (Θ , Φ) WITH STRAIN AMPLITUDE ($\gamma_{\max}$).

4. Appendix A. Constants A and B

Tabulated formulae for the constants A and B in formulae (1)–(8) are given below.

	Cone and Plate (cone angle Radios R)	Ring and Plate (Ring radii R_1 , R_2 gap h)	Parellel Plate (Radius R gap h ar radius r)	Concentric Cylinder (Annulus radii R_1 R_2 liquid height l)
A.	α	$\frac{h}{R_1}$	$\frac{rh}{R^2}$	$\frac{R_1^2 - R_2^2}{2R_1 R_2}$
B.	$\frac{3\alpha}{2\pi R^3}$	$\frac{2h}{\pi (R_1^4 - R_2^4)}$	$\frac{2h}{\pi R^4}$	$\frac{R_1^2 - R_2^2}{4\pi R_1^2 R_2^2 l}$

These formulae are approximate, except in the case of the parrallel plate geometry which are exact if the ideal flow pattern is obtained.

Appendix B. Interpreting Data

There are two fundamentally different schemes of interpreting experimental data, these two schemes are outlined below. The first is commonly used by theoreticians interested in testing hypothetical relaxation spectra the point of departure is the assumption of a theoretical rheological model and the end point is the comparison of theoretical predictions of amplitude ratio and possibly phase angle between the moving platens with the experimentally observed values.

A more useful practical alternative is the second approach in which the velocity flow pattern within the material is assumed and the end point is the calculation experimental viscosity of rigidity modules. These quantities be further treated to obtain relaxation spectra if required.

Scheme 1

- (1) Assumption of theoretical rheological model and boundary conditions.



- (2) Prediction of motion of free member. (Amplitude ratios and phase angles v frequency).



- (3) Comparison with experimental observations of amplitude ratios and phase angles.

Scheme 2

- (1) Assumption of velocity pattern.



- (2) Calculation of complex viscosity or rigidity modulus from experimental observations.



- (3) Comparison with theoretical model if required.

Appendix C Extending the Frequency Range

With the 1500 r.p.m. motor the upper frequency of the rheogoniometer is 25 Hz. This may be extended to 50 Hz by fitting the 3000 r.p.m. motor, but this frequency represents the upper limit to be obtained by increasing the drive frequency.

The DTFA is able to look at harmonics of the fundamental of the oscillatory frequency and this immediately raises the possibility of extending the frequency range of the rheogoniometer in the *linear* region of material response.

The oscillatory motion of the lower platen may be made non-sinusoidal by *partially* disengaging the worm drive shaft from the worm wheel with the adjusting screw located in the base front of the instrument. The actual components of motion of the bottom platen may be obtained by clamping top and bottom platens together, and using a *low* fundamental frequency a harmonic analysis of the transducer signal may be made with ease by feeding a signal from the transducer meter into the DTFA.

In testing a material in the *linear* region of response there will be a one to one correspondence between the components of motion in the two platens at each component frequency of the input motion. Suppose that there are N sensible components of the input motion then a test at one motor speed will be equivalent to N separate tests done with purely sinusoidal input motion.

The upper frequency limit of the DTFA is 159.9 Hz and so at the upper motor speed which produces 50 Hz it is only the 3rd harmonic which is useful, and the upper oscillatory frequency is 150 Hz.

The upper limit may be considerably raised by using a tape recorder as a frequency changer. By recording at a high tape speed and playing back into the DTFA at a lower tape speed frequency division is achieved. The Elliot-Tandberg twin-track tape recorder is fully compatible with both the rheogoniometer and the DTFA.

Appendix D. The Check for Non-Linearity

The usual check for material non-linearity in oscillatory motion is to carry out experiments over a frequency range for several different amplitudes of the lower platen. This is a very tedious technique and quite unnecessary as a harmonic check can be made in a few cycles of motion, typically taking less than a minute, by using the DTFA.

Of course there is a capital cost involved in using the DTFA, but the on-line check afforded by this method is perhaps 1,000 times faster than carrying out a complete repeat experiment and computation and it could probably be justified on these grounds alone.

The value of this technique is restricted to sinusoidal motions of the lower platen.

5. Notation

A, B	Instrument constants detailed in Appendix A.
I	Moment of inertia of free (top) platen.
K	Torsional stiffness of torsion bar.
Θ	Angular amplitude of driven (lower) platen.
Φ	Angular amplitude of free (top) platen.
Φ', Φ''	Real and imaginary components of angular amplitude of free platen.
μ^+	Complex viscosity.
μ', μ''	Real and imaginary components of viscosity.
$\hat{\mu}^+, \hat{\mu}^+$	Successive approximations of the complex viscosity.
ω	Circular frequency of oscillation.

6. References

- ¹ Harris, J and Bogie, K. Rheol. Acta, 1967, 6, 3.
- ² Harris, J., Solartron News, Tech. Suppl. 1967, No. 2. p. 3.
- ³ Harris, J., Nature 1968, 217, 1248.
- ⁴ Harris, J. and Bogie K., Rheol. Acta., 1968.
- ⁵ Harris, J. and Wilkinson, W. L. Chem. Eng. Sci., 1969, 24, 1.
- ⁶ Leaderman, H., Rheology, Vol. 2, p. 1. Ed. Eirich. Academic Press 1958.
- ⁷ Oldroyd, J. G., Jour. Mech. and Appl. Math. 1951, 4, 271.
- ⁸ Oldroyd, J. G., Strawbridge, D. J. and Toms, B. A., Proc. Phys. Soc., 1951, B64, 44.
- ⁹ Toms, B. A. and Strawbridge, D. J., Proc. 2nd Int. Cong. Rheol. p. 99. Butterworths 1953.
- ¹⁰ Toms, B. A. and Strawbridge, D. J., Trans. Faraday Soc. 1953, 49, 1223.
- ¹¹ Sangamo Controls Ltd. Weissenberg Rheogoniometer Instruction Manual, Model R.18. Sussex, England.
- ¹² Solartron Electronics Ltd. Digital Transfer Function Analyser Manual. Model JM1600, Farnborough, England.

COMPUTER PROGRAM CATALOGUE

In the 4th edition of the Bulletin in 1968 several new features were introduced, one of them being the Computer Program Section which is intended as a vehicle for the dissemination of computer program information of use to rheologists.

It is too early at the time of writing to judge the initial response of program authors to the invitation made in the last Bulletin, that program details be notified to the Society for the purpose of compiling a catalogue.

Two further significant developments of this service have taken place in that the Computing Laboratory of the University of Bradford will now accept data processing in rheology as a service to members of the British Society of Rheology. Secondly, rheologists need to characterise solid-liquid systems and powders by obtaining size distribution data of the divided solids using instruments such as the Coulter Counter. Very recently the Catalogue of Coulter Counter Computer Programs, compiled at the University of Bradford, has become available. It is described below.

Data Processing Service (I.C.L. 1909)

As a complimentary facility to the publication in the Bulletin of program abstracts it has been arranged that data processing for members can be accommodated in the Computing Laboratory at the University of Bradford. It is realised that many potential program users would wish to use their own facilities which are probably free and convenient, but a few may not be so well endowed and it is really with these users in mind that the service has been created as an alternative to obtaining a service at the original source of the program. With this facility in existence there should be scarcely anyone who is aware of an available program they would like to use and yet is unable to obtain a service.

Not all language facilities are available for use in the Computing Laboratory at Bradford; none availability will be indicated on the published abstract.

Standard charges at present operating rates for data processing are as follows:

1. Data preparation—£2 10s. per hour (it is preferable for users to prepare data themselves).
2. Computing—Commercial and Industrial users £60 per hour. Educational establishments by individual arrangement.
3. Graph plotting—£12 per hour.

Potential users of this service may contact:

Dr. R. J. Ord-Smith,
Computing Laboratory,
The University,
Bradford 7,
Yorkshire, U.K.
Tel. No. Bradford 29567, Ext. 217.

Coulter Counter Computer Program Library

Many of the essential features of the Computer Program Catalogue for the field of Rheology are already evident in the recently published Catalogue relating to Coulter Counter Programs. Copies of the Catalogue are available from Dr. R. J. Ord-Smith at the address given above.

The Catalogue is a collection of some 21 program abstracts from various sources, all relating to the Coulter Counter. Further editions of the Catalogue will be published from time to time as the accumulation of abstracts dictates.

BRITISH SOCIETY OF RHEOLOGY

Computer Program Catalogue Publication Abstract

1. Author
.....
2. Establishment
.....
..... Tel. No.
3. Program Abstract
.....
.....
Input Data
.....
Output Data
.....
4. Program date
5. Language
6. Computer requirements
.....
7. Type of Input/Output
.....
8. References
.....
.....
.....
9. Related programs
.....
10. Available for copy/data processing
.....
.....

Return to: Dr. J. Harris,
Postgraduate School of Chemical
Engineering,
University of Bradford,
Bradford 7, U.K.

Additional blank abstract sheets are available as required from the above address.

PROJECT REPORTS

The bulk of the work in the published scientific literature is concerned with reporting investigations which have been drawn to a more or less definite conclusion, even on the date of publication the work reported is history and allowing for writing-up time, refereeing and printing, the time-lapse between termination of a project and publication of results may typically be of the order of eighteen months. (Authors submitting work to the Bulletin can, however, expect a significantly reduced lapse.)

Most people with an interest in rheology are as keen to learn not only what *has* been done but also about work currently *in* progress. This is helpful in forward planning of research and also in knowing where to seek discussion and information.

It is intended to set aside space in future editions of the Bulletin in which summaries of *current* projects can be published without authors feeling that any special commitment arises out of the publication. It is fully understood that the emphasis, or indeed the general theme, of a project may not remain constant and revised summaries could be published as the occasion arises.

A brief summary of about 100 words describing the project should be sufficient to acquaint readers with the salient features and overall give an indication of work presently in progress in the field of rheology.

NEWS FROM FRANCE

In 1968 membership of Groupe Français de Rheologie was 255 ordinary and 72 collective members, of whom 32 and six respectively were resident outside France. Professor Weiss has been elected as an Honorary Member, in recognition of his services in the development of rheology in France and his role in the creation of G.F.R.

Four short meetings of the group were held during the year, in addition to those organised by the Lyon branch; approximately 20 members presented contributions at the International Congress held in Kyoto. After discussing the situation with members, the officers of G.F.R. have submitted to the International Committee of Rheology an invitation to hold the Sixth International Congress at Lyon in 1972.

Editorial difficulties have unfortunately delayed publication of "Cahiers," and Volume 1 No. 6* did not appear until the turn of the year. Publication of 2 (1) was expected at the end of February, 1969. Increasing production costs for "Cahiers" have rendered necessary an increase in the annual subscription.

The project on rheological terminology was not extended during the year, but a further meeting was arranged in January, 1969. The 80 definitions agreed earlier have now been published; first in the

proceedings of the INSA conference at Lyon, September, 1967; and also in *Annales de l'Institut Technique du Batiment et des Travaux Publics** (1968), No. 252, 1762-1772.

The proceedings of the INSA conference mentioned earlier form a book of 180 pages published in 1968 (Ed.: Masson). In addition to the list of definitions the volume contains papers on: of rheological behaviour (J. Mandel); models and functions of linear viscoelasticity (J. M. Pierrard); non-linear models (B. Persoz); three-dimensional generalisation of linear viscoelasticity and classical plasticity (D. Radenkovic); stationary and non-stationary vibrations of viscoelastic bodies; determination of complex moduli (N. P. Vinh Tuong); creep of metals (G. Murry), rheology of polymers (G. Vallet and C. Smadja); rheology of suspensions (R. Zangger).

A copy of the two publications marked * may be borrowed on application to: Dr. D. Hadley, J. J. Thomson Physical Laboratory, Whiteknights, Reading, RG6 2AF.

THE EARLY HISTORY OF THE BRITISH RHEOLOGISTS' CLUB

There have been, during the past year, several requests from members for information on the formative years of the Society, or as it was originally called "The British Rheologists' Club." As always on such occasions one turns to George Scott Blair, and as usual he has been able to supply the answers—this time by unearthing a stack of early "Bulletins," from which all the ensuing information has been extracted.

For a description of how the Club began one cannot better the account given by the late H. R. Lang (for long the Secretary of the Institute of Physics) in the form of a letter to the editor, published in *Bulletin of the British Rheologists' Club*, No. 13, December, 1946 (Price to non-members, 5s.).

"My dear Scott Blair,

Some time ago you asked me to jot down my recollections of how the Club came into being, and something of its first few years. Please take these jottings as my hurried attempt to meet your request—I never could resist them. One can never tell who in the future will peruse these scribbles and what they will read into them. If they do no more than help to keep something of that delightful informal spirit with which we started, I shall be more than pleased. Here, then, is my own story:

"It was a fine summer afternoon in 1940 and, feeling somewhat exhausted by the difficult war conditions of evacuation to Reading, I went a little way into the country with my wife. Begrudging the few hours away from the temporary office of the Institute of Physics, I

consoled myself by fulfilling a long-standing promise to visit Scott Blair's laboratory at the National Institute for Research in Dairying, at Shinfield, some three miles out of Reading. He explained to me the difficulty he was having in devising suitable instruments for measuring the rheological properties of the secretions from the uterine cervix of the cow, which he thought might prove a useful early test for pregnancy—a matter of great importance to the dairy industry during the war. It immediately occurred to me, from what he said, that this problem was very similar to V. G. W. Harrison's, who was trying to measure the rheological properties of printing inks. In the normal course of my work as Secretary of the Institute of Physics, I therefore gladly arranged for these two to meet. That meeting must be taken as the first meeting of the Club, that it was of mutual benefit seems certain, for they came to me and asked if there were not a few more interested in these problems, and that I should bring them all together. There were the paint industry people, the oil and tar people, and so on, and we thought there might be 20 or more who would ilke to lunch together two or three times a year to 'swop yarns,' and to arrange to visit each other's labs. We three appointed ourselves a Committee, having decided to form a Club, which should have no rules and no formalities like scientific and learned societies—indeed, a Club, where one could speak as freely as in the lab. The Committee was to meet either in my attic room in the University of Reading (the old red building) or in Scott Blair's drawing-room. The latter were the more successful meetings since we had the great advantage of Mrs. Scott Blair's wisdom and teas, not to mention Wolfgang, the dog, who was always present. Harrison came over from Guildford on his motorbike—dressed as for Arctic exploration, which was no doubt necessary. The Board of the Institute of Physics permitted the clerical work for the Club to be done in its temporary office for the first few years of its existence, so long as it did not interfere too much with official work. When it did, Mrs. Lang came to the rescue and cut the stencils for the Bulletins and Abstracts, which were then rolled in my office. The Committee meetings were great fun—as we all had a goodly dose of Committee work in our daily work we were glad to have these most informal meetings, breaking all the rules of procedure. Later when we found that the Club was shockingly successful, and we were in danger of founding yet another scientific Society, with its publications and office problems, we thought it wise to make the Committee more representative of the Club, so Treloar and Broome joined us. They thought it time we had a Chairman and I had the honour of being pushed into that office. This I was glad to accept, for I confess I used to try out techniques learnt from Chairmen I had seen at work during the last 10 years. Perhaps some less biased pen than mine will record something of the Committee's thereafter.

“As the Club grew in numbers and status, its office work grew.

There was the idea, for example, of producing duplicated copies of translations of original classical rheological papers; in particular one by Pochettino which ran to many pages of typescript. This was done in odd times in my office and was very troublesome. Indeed, in 1942, the time had clearly come to take the Club's activities more seriously before they become a menace and I discussed the matter with the Officers of the Institute of Physics and the Club. The upshot was that the Institute continued its support for another year when Scott Blair and Harrison agreed to carry on, with such help as they could get. The Club by then was the proud possessor of a Post Office Account and a rubber stamp, which were used effectively to persuade Miss Mary Milligan, a friend of the Scott Blairs', to do the office work for a very modest fee, but the Institute's duplicator and addressing machine continued to be of service to the Club for a while.

"In the 'Reading' days the Club tackled such trying problems as 'Pi,' and the classification of deformations of materials. It may have been a case of 'fools rush in where angels fear to tread,' but we did enjoy ourselves! Exchange of views was frank and free and often I regret to say I felt that the experts knew no more about what was being discussed than I, as Chairman, did—and said so. In view of the later developments, I am not so sure that the old adage 'there is many a true word spoken in jest' is not applicable in this instance!

"I hope that Scott Blair and Harrison will add to these notes, and fill in the parts I have missed and modify any exaggerations. They must not fail to say something about the first weekend Conference, when the Scott Blairs were able to re-live the early scenes of their Oxford romance in her old College—St. Hilda's—in which the Conference was held.

H. R. LANG.

"[Dr. Harrison and I have nothing to add but we welcome this opportunity of putting on record the very informal way in which the Club had its beginnings, nor shall we forget the debt we all owe to Dr. Lang, and to the Institute of Physics for their invaluable help in the early days of our Club.—EDITOR.]"

Dr. Scott Blair keeps a complete set of "Bulletins," with the exception of No. 1, which he has mislaid. If any member has a spare copy of Bulletin No. 1, or would be prepared to make a photo-copy of that issue, it would be received with gratitude by Dr. Scott Blair. (Address: Grist Cottage, Iffley, Oxford.)

The first eight issues of the Bulletin were duplicated from typescript, but as membership increased a printed layout became possible. At first no printer's name appears, but when, in 1950, anonymity is cast aside, we see the name Fletcher and Co., Farnborough, who are still acting in the same capacity. The style was unchanged for several

years before 1950—except that in 1947 the Bulletin first appeared in a card cover—and so one can assume that the present happy relation with Messrs. Fletcher extends back for well over 20 years.

Until 1958 the Bulletin included (or rather consisted largely of) abstracts, and for that reason was available to non-members at 5s. an issue. It is salutary to think that the annual subscription to the Society has remained unchanged for more than 25 years, whilst the non-members' subscription to Rheology Abstracts has increased by more than 1,100 per cent. in 11 years.

With the separation of R.A. and its publication on a commercial basis the Bulletin diminished in importance. Its page size was reduced to match that of R.A., and although the amount of general news did not diminish the Bulletin looked very forlorn, standing on its own as an eight-page pamphlet with only thin paper covers. Gradually, however, the Bulletin has been built up in its own right, and now looks ahead to a thriving future as a publication containing serious scientific reports, as well as general news and conference reports. Will the next stage see the transfer of the Bulletin to commercial production available generally (already its subsidised production costs account for the *total* annual membership subscriptions), with notes and news relegated to a members' newsletter?

From the first the dissemination of rheological information was considered an important part of the Club's role; interpreted in the widest sense it was the sole reason for its foundation, and the Society's recent concern with the improved retrieval of rheological information is no more than a return to the aims of our founder members.

Bulletin No. 1 contained about 30 abstracts (not having seen that issue I would be interested to hear details of abstract No. 1), and the number rapidly built up to about 100 per issue, i.e. 400 per year. The issue for September, 1951, contained 134 abstracts, together with melancholy articles from Drs. Harrison and Scott Blair explaining that because of financial problems the scope of abstracts would need to be *reduced*. It was decided that "as far as possible we shall continue to draw readers' attention to all papers of rheological interest published; but about half of these will be cited by title only. These papers will be from readily accessible journals . . . which normally contain so many rheological papers that no rheologist . . . can afford not to read them regularly. Of the remaining papers about one quarter will be abstracted very briefly . . .; the remainder, comprising mainly papers from trade journals and not readily-accessible foreign periodicals will continue to be abstracted in full." Indeed a contrast with today, when the *cri de coeur* is for additional abstractors to provide more abstracts.

Undoubtably, 20 years ago, percentage coverage of the literature was much superior to that achieved by Rheology Abstracts today.

Assuming rheological publications to have increased at the same rate as the rest of science one would anticipate that current abstracts would number about 1,500 per year: the actual rate is about 650.

The above figures should not be interpreted as implying that members of the Society are now less effective than previously in supplying abstracts, since the ratio of abstracts supplied to members resident in Britain can have changed little over the years. In Bulletin No. 13 (December, 1946) it is announced that membership is no longer restricted to rheologists working in Britain and the Commonwealth, and that applications for membership from foreign countries will be considered. The same issue contains accounts for the previous financial year (why was the end of this year later changed from September 30th to June 30th?), which show that membership was well in excess of 200; at present, members resident in Britain total not quite 400. Comparing these figures with the number of new members elected each year it becomes obvious possibly as befits a Society with our aims that the membership itself is in a state of continuous non-uniform flow.

Some activities of the Club have now disappeared without trace, presumably through disuse as a consequence of greatly improved national library services. Early Bulletins contain several references to translations of foreign language papers prepared by the Club, and there are notes concerning reprints and books presented to the Club library.

Meetings in the early years appeared to be on a much more informal basis than at present, although the Annual Conference in September was of early establishment. There were many more meetings than has been the custom recently, most of them being short and not intended for a large attendance. The list of meetings given in Bulletin 1965, No. 2, is obviously far from complete as regards the 10 years of the Club's existence. Nowadays there seems to be a fear of holding meetings away from large cities or central areas, a fear that obviously did not exist in 1947, when the Club penetrated as far west as the St. Austell clay workings (this is not a hint to a member of the present Council!). In 1946 the Committee felt "that although the time has not yet come to start Branches of the Club in the Provinces, there should be more activities outside the London area. It is hoped that groups of members will form *ad hoc* Committees to organise joint meetings of the Club with branches of other scientific societies in their localities. Although all members would, of course, be welcome, these meetings would be specially planned to meet local needs. Local representatives might be appointed to the Committee of the Club . . . in much the same way that Mr. W. A. Richardson now represents the Manchester area. In this way it should be possible to extend the activities of the Club without increasing the burden of work on the Hon. Secretary and Committee." It still seems a good idea.

Some features recur time and again throughout the history of the Club and Society; letters on rheological nomenclature crop up from time to time (have these been studied by the members of the present BSI Committee?); and as long ago as 1947 members were "invited to write to the Editor putting any problems or questions which it is thought might evoke useful replies from other members, or offering any comments on rheological matters which might not be brought to members' attention through the usual channels of publication" (the invitation still holds).

By 1950 "the proposal to change our name to British Society of Rheology or its equivalent has aroused a certain amount of comment, and some of the correspondence received (was) reproduced. It is clear that opinion is divided on this question." Perhaps what swayed the issue was the letter sent by R. H. S. Robertson: "I quote from Sir Wm. Huggins' 'The Royal Society.' The Royal Society arose out of a small club, of 'divers worthy persons, inquisitive into natural philosophy, and particularly of what was called the New Philosophy, or Experimental Philosophy.'

"A few years ago I strongly opposed a *premature* change of name. The time has now come and I approve of 'The British Society of Rheology.'"

We all know that the change of name was approved, and it is interesting to note that the 1951 Committee of The British Society of Rheology included Dr. L. Grunberg, and Dr. B. S. Neumann.

(As a relatively recent member of the Society I have had to compile the above notes from documentary sources. Perhaps the picture could be clarified by the personal reminiscences of one of our earlier members.)

D. W. HADLEY.

[A few copies of the following Bulletins are available, on receipt of 4d. stamp, from Dr. D. W. Hadley, J. J. Thomson, Physical Lab., Whiteknights, Reading RG6 2AF.: 1946, December; 1947, March, June; 1949, September; 1950, June; 1962 (3). 1963 (1); 1964 (3) (4); 1965 (1); 1966 (2) (4); 1968 (2) (3).]

IMPRESSIONS OF THE FIFTH INTERNATIONAL CONGRESS ON RHEOLOGY

By J. F. Hutton

Shell Research Ltd., Thornton Research Centre, P.O. Box 1,
Chester, CH1 3SH

The setting for the Fifth International Congress on Rheology, held on October 7th–11th, 1968, was the International Conference Centre in Kyoto, Japan. For administrative excellence, architectural interest, scenic beauty, comfort and hospitality it could not have been bettered. The Centre stands on a lake at the northern edge of Kyoto and is bordered on three sides by tree-covered hills. The building is an example of "engineering" architecture which makes the structural skeleton the main feature. In this example the principal bones are arranged to give the impression of an X-shaped cross-section. I liked the design but I heard differing opinions. Although the outside of the building aroused controversy, it was generally agreed that the inside was wholly excellent. Two large lecture halls and a number of smaller rooms were sufficient to accommodate two international conferences concurrently. Facilities were provided for meals and refreshments, shopping and mailing. Members of the secretariat were always on duty to render assistance both inside and outside the lecture rooms. And as a reminder to congress members that they were in Japan, and not in any other country, there was a tea house in the garden. Here, for 150 yen (3s. 6d.), one could have green, frothy tea served with the traditional Japanese ceremony—in a shortened form for impatient Westerners.

About 470 attended the Congress, including 300 Japanese, 100 Americans and 45 West Europeans.

Six papers were given in plenary session and a little over 300 in five concurrent sessions. This arrangement is customary at the International Congress but it must be critically examined by future Organising Committees to minimise the clashing of related topics, and to allow ample time for private discussions, social occasions and visits. I thought that too much time was given over to papers.

About half of the papers were devoted to polymers and polymer solutions and the rest were divided about equally between disperse systems, theory, biorheology and others. Since my own interests range from polymer solutions and melts through disperse systems to theory I found it desirable to be in two places at once. The following comments are necessarily limited to only a few of the many contributions.

In his Presidential Lecture, J. D. Ferry (University of Wisconsin) talked about the concept of entanglements in polymer systems. The concept dates from the early 1930's, but the author confined his

remarks to its use as a necessary development of the molecular theories of Rouse and Bueche. The long-time components of the relaxation-time spectrum are ascribed to the slipping of entanglements past each other. This view has been supported by a considerable amount of experimental work and, in recent years, has formed the basis of successful theoretical developments by Graessley and Chomppf and co-workers. The lecturer suggested that the phenomenon of "overshoot" may be another consequence of entanglements. Overshoot is the name given to the occurrence of a peak in the stress-time functions at the beginning of an experiment carried out at constant rate of shear.

A paper by A. A. Trapeznikov (Academy of Sciences, Moscow) was devoted to overshoot in polymer solutions and its explanation in terms of structural breakdown. S. Ueda and T. Kataoka (Textile Research Institute, Tokyo) observed overshoot in shear stress and normal stress with polyethylene melts. W. E. Lewis and R. S. Brodkey (Ohio State University) have modified an empirical kinetic theory to include such time-dependent phenomena as overshoot.

Historically, the concept of entanglements led along a different path with the publication of the network theories of Yamamoto and Lodge. At the Congress, A. S. Lodge (University of Wisconsin) gave an outstanding talk in which he compared the network model with the bead-spring models of Rouse, Zimm and others. He emphasised the conceptual difficulties of bead-spring models and the failure of these models to predict correctly the dependence of moduli on concentration. On the other hand, although the network model has the unsatisfactory assumption that the junctions move affinely, it successfully represents a wider range of experimental results than do the bead-spring models. In some respects the predictions of the two models are identical. This arises because although the equations describing the details of the molecular models are fundamentally different they combine to give similar constitutive equations. In the discussion J. D. Ferry pointed out that at very low concentrations the network model runs into a conceptual difficulty, a point conceded by the lecturer.

There were many papers describing experimental work. Measured values of shear stress and normal stresses were compared with values predicted by theory and agreement was sometimes found; sometimes not. A disturbing conclusion was reached by D. J. Meier Shell Development Co., Emeryville); namely, that it is doubtful that any reliable data exist on the effect of high velocity gradients on the viscosities of dilute polymer solutions. His evidence for this conclusion was obtained from measurements made in helical flow between concentric cylinders in which for dilute solutions, but not concentrated solutions, the viscosity in the axial direction was smaller than the viscosity in the circumferential direction. The results were rationalised by postulating a migration of molecules from the wall. It was suggested that the concentration at which the wall effect no

longer exists may be that at which a network of polymer molecules forms.

A fashionable experimental method is to combine continuous shear and oscillatory shear. M. Tamura, M. Kurata and K. Osaki (Kyoto University) were amongst the first to use this method systematically. These authors presented their latest results on moderately concentrated polystyrene solutions in chlorinated diphenyl. A paper was read for H. Markowitz (Carnegie-Mellon University) discussing the application of the method of combined shear to fluids with fading memory. K. Walters (University of Wales, Aberystwyth) presented an analysis which showed, for example, that for third-order simple fluids the results in combined shear are not the summation of the results of the individual shear motions.

The General Lectures were given by A. J. Staverman (Leyden University) on "Thermodynamics of rheological behaviour," R. Meredith (University of Strathclyde) on "Dynamic mechanical properties of textile fibres," F. H. Müller (University of Marburg) on "Reversible mechanical effects in the glassy and viscoelastic state," R. S. Marvin (National Bureau of Standards, Washington, D.C.) on "Rheological models and measurements," and H. Kawai (Kyoto University) on "Mechanical anisotropy of crystalline polymer in relation to molecular orientation."

There were groups of papers on the fracture of polymers, on molecular orientation in polymers, on spinning, on the Barus effect, on the Toms effect, on rheo-optics, on flow stability, and on a number of other topics.

On the first evening of the Congress the President of the Japanese Scientific Council held a reception in the Kyoto Tower Hotel. There the Western guests valiantly attempted to drink sake from little wooden boxes and to eat a range of delicacies, including a sort of spaghetti, using chopsticks, but our hosts had thoughtfully provided alternative utensils for those who needed them. Geishas were present to look decorative and to keep the beer-glasses filled, and a programme of dances was given by a group of maiko. The Congress Banquet was held at the Miyako Hotel. A sumptuous meal was enlivened by the presence of wives of delegates and of some of the young ladies of the Congress secretariat. Following speeches from representatives of each country present a set of dramatic traditional dances was presented.

(It is hoped to prepare a list of titles of papers and authors in time for the next edition of the Bulletin.—Ed.)

General Headings of Papers:

General Lectures

Polymer Solids

Elastomers

Blends and Foams

Fracture

Interfacial Phenomena

Molecular Motions

Orientation and Deformation Mechanism

Polymer Solutions and Melts

Solutions

Nonlinear Phenomena

Melts

Fibre and Film Formation

Blends and Copolymers

Flow through Duct

Metals and Ice

Rheo-optics

Polymer Solids

Relaxation and Creep

Viscoelastic Behaviour

Fracture

Theory

Solid Mechanics

Complex Systems and General

Constitutive Equations

Fluid Mechanics

Measurements

Wood, Food and Fruit

Glass, Concrete and Clay

Soil and Rock

Biorheology

Blood and Blood Vessel

Other Biological Systems

Disperse Systems

The above list was taken from the contents list of Abstracts of the 5th International Congress on Rheology.

PERSONAL NOTES

Dr. M. F. Culpin would like to advise prospective correspondents that his new home address is: Delfryn, Star Road, Penperlleni, Pontypool, NP4 8ST, U.K. Telephone No.: Nantyduerry 253.

Reclassification of Members' Interests

In the last issue of the Bulletin (No. 4, 1968) Members were notified of a new classification of rheological activities and a form was provided for return of information.

Members of the Society are urged to complete and return their forms at an early date to: Dr. D. W. Hadley, J. J. Thomson Physical Laboratory, Whiteknights, Reading, RG6 2AF. The Editor of the Bulletin is presently able to supply a few spare copies of the form to those who require them.

PROGRAM. 39th ANNUAL MEETING. THE SOCIETY OF RHEOLOGY, INC. (U.S.A.)

January 13th-15th, 1969

- I. M. Krieger, Case Western Reserve University, Cleveland, Ohio, "Monodisperse Colloidal Suspensions of Spherical Particles."
- B. D. Coleman, Mellon Institute, Carnegie-Mellon University, Pittsburgh, Pa., "Shear Waves as a Possible Cause of Melt Fracture."
- R. A. Mendleson, W. A. Bowles, F. L. Finger, Monsanto Company, Texas City, Texas, "The Effect of Molecular Structure on Polyethylene Melt Rheological Behaviour."
- R. A. Stratton, Mobil Chemical Company, Edison, New Jersey, "Non-Newtonian Flow in Polymer Systems with No Entanglement Coupling."
- W. N. Findley and K. Onaran, Brown University, Providence, Rhode Island, "Product Form of Kernel Functions for Nonlinear Viscoelasticity of PVC Under Constant Rate Stressing."
- J. S. Y. Lai and W. N. Findley, Brown University, Providence, Rhode Island, "Prediction of Uniaxial Stress Relaxation From Creep of Non-Linear Viscoelastic Material."
- R. A. Dickie and T. L. Smith, Stanford Research Institute, Menlo Park, California, "Stress-Strain Characteristics of an SBR Vulcanizate in Simple Tension, Constrained Biaxial Tension and Equal Biaxial Tension."
- K. L. Cheng, Lord Corp., Erie, Pa., "A Strain Energy Function for Rubber-like Materials."

- K. C. Valanis, Iowa State University, Ames, Iowa, "Elastic Materials with Particle Interactions of Finite Range."
- H. K. Mueller, California Institute of Technology, Pasadena, California, "Some Mechanical Properties and the Surface Energies of a Swollen and Unswollen Polyurethane Elastomer."
- E. Menefee, Western Regional Research Laboratory, Albany, California, "Improvements in Viscoelastic Theory for Polydisperse Entangled Macromolecules."
- J. Rotne and S. Prager, University of Minnesota, Minneapolis, Minnesota, "Variational Treatment of Hydrodynamic Interaction in Polymers."
- F. Bueche and G. Tokcan, University of Dayton, Dayton, Ohio, "Range of Validity of the DTO Model."
- P. J. Carreau, The University of Wisconsin, Madison, Wisconsin, "Rheological Equations From Molecular Network Theories."
- N. Sarkar, The Dow Chemical Company, Midland, Michigan, "Viscosity of Polymer Solutions as a Function of Shear Rate."
- J. L. Sutterby, The Dow Chemical Company, "Zero Shear Rate Viscosity by Falling Sphere Viscometry. I. Wall, Inertial, and End Corrections to Stokes Law for Newtonian Fluids."
- R. F. Scott, California Institute of Technology, Pasadena, California, "The Application of Rheology to Soil Mechanics."
- R. L. Schiffman, University of Illinois, Chicago, Illinois, "Secondary Consolidation of Clays—A Viscoelastic Analysis."
- J. L. Ericksen, The Johns Hopkins University, Baltimore, Maryland, "Some Ordinary Differential Equations Pertaining to Liquid Crystals."
- B. Bernstein and R. L. Rosdick, Illinois Institute of Technology, Chicago, Illinois, "Some Rheological Relations for Small Oscillations Superposed on Large Steady Shear of Non-Newtonian Fluids."
- H. Leeming and W. G. Knauss, Lockheed Propulsion Company, Redlands, California, "Constitutive Behaviour of Polymers Under Transient Thermal Conditions."
- A. Siflinger and A. Silberberg, Weizmann Institute of Science, Rehovot, Israel, "The Mechanical Stability of Viscoelastic Jets."
- R. I. Tanner, Brown University, Providence, Rhode Island, "The Use of Iterative Numerical Methods for the Solution of Integral Equations Arising in Rheology."
- A. C. Pipkin and R. I. Tanner, Brown University, Providence, Rhode Island, "Intrinsic Errors in Pressure-Hole Measurements."
- R. C. Penwell and R. S. Porter, University of Massachusetts, Amherst, Massachusetts, "Rheology of Polystyrene Near the Glass Transition."

DIARY

Meetings (1969)

- 13-18 April. 2nd International Conference on Fracture (Brighton). Dr. A. H. S. Mutton, Secretary, Fracture Conference Office, B 77 AERE, Harwell, Didcot, Berks.
- 17 and 18 April. Conference—Practical Rheology in Polymer Processing. Joint B.S.R.—Plastics Institute Meeting. (To be held in London.)
- 17 April. Symposium—Lubrication and Wear of Joints (Leeds). Dr. V. Wright, School of Medicine Rheumatism Research Unit, 44 Clarendon Road, Leeds LS2 9PJ.
- 8-10 May. Seminar—Rheology (Louvain, Belgium). Dr. J. Mewis, Dept. of Chemical Engineering, de Croylaan 2, Heverlee, Belgium.
- 16-21 June. Congress—International Federation of Automatic Control (Warsaw, Poland). Organising Committee, IVth IFAL Warsaw UL. Czackiege 315, P.O. Box 903, Poland.
- 2-6 September. Conference—International Convention on Education and Training Technology. (Grosvenor House, London.) The Secretariat, The Institution of Electrical Engineers, Savoy Place, London, W.C.2.
- 22-26 September. Conference—Tribology in Iron and Steelworks. (Royal Garden Hotel, Lancaster Gate, London.) The Iron and Steel Institute, 4 Grosvenor Gardens, London, S.W.1.

Meetings (1970)

- 7-10 April. Conference—4th International Conference on Stress Analysis. (Cambridge.) The Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1. (Not 1969 as previously advertised.)
- 1-5 June. Conference—6th International Conference on Non-destructive Testing. (Hannover, Germany.) Sekretariat 6 ICNT, 3 Hannover (Germany), Postfach 1424.

Exhibitions (1969)

- 25-29 August. Data Fair 69 Manchester. The British Computer Society, 23 Dorset Square, London, N.W.1.

Recent Elections

NAME AND ADDRESS	INTERESTS
W. J. Bontinck, Doc.es Sci., U.C.B.—SIDAC Division, Research Department, Ottergamse Stwg. 801, Ghent, Belgium.	Polymers, polymer solutions, printing inks.
A. G. Dodson, B.Sc., Appl. Maths. Department. U.C. Wales, Penglais, Aberystwyth, Wales.	General, rubbers, polymers, polymer solutions.
G. Eberhardt, Phys. Ing., Contraves Industrieprdukte GmbH, Stuttgart—Vaihingen, Holzhauser Str. 16. W. Germany.	Polymer solutions and melts, liquids, food products, biological substances.

NAME AND ADDRESS	INTERESTS
R. Gerlach, Dipl. Ing., Dr. Ing., Mineralölwerke Peine, 315 Peine, Schäferstraße 2, Germany.	Lubricating grease.
H. Gravert, Dipl. Ing. Dr. Techn., Mineralölwerke Peine, D—315 Peine, Schäferstraße 2, Germany.	Lubricating grease.
A. G. Guy, B.Sc., Grad. Inst. P., Applied Maths. Department, The University, Liverpool 3, U.K.	General, polymer solutions, glasses, ceramics.
V. S. Kamat, B.Sc., M.Sc., Dr. Tech. Chem., Interkeller AG, Schärenmoos Str. 105, 8052 Zurich, Switzerland.	General.
T. P. Kelly, B.Sc., Gestetner Limited, Broad Lane, London, N.17.	Emulsions, suspensions, printing inks.
R. V. Maheswari, M. Tech., M.Sc., Schools of Chemical Engineering, The University, Bradford 7, Yorkshire, U.K.	General, rubbers, polymers, polymer solutions, emulsions, suspensions, pharmaceuticals, paints, printing inks.
D. Popplewell, B.Sc., Shoe and Allied Trades R.A., SATRA House, Kettering, Northants, U.K.	General.
A. K. M. Abdul Quader, B.Sc., Schools of Chemical Engineering, The University, Bradford 7, Yorkshire, U.K.	General, rubbers, polymers, polymer solutions, emulsions, suspensions, pharmaceuticals, paints, printing inks.
J. H. Richards, B.Pharm., Ph.D., Ph.C., School of Pharmacy, Regional College of Technology, Leicester, U.K.	General, emulsions, suspensions, pharmaceuticals, etc.
C. A. J. Russell (Miss), B.Sc., Department of Applied Mathematics, U.C. of Wales, Aberystwyth, Wales.	Rubbers, polymers, polymer solutions.
E. A. Vaughn, B.Sc., M.Sc., Department of Textile Technology, U.M.I.S.T., Sackville Street, Manchester 1, U.K.	General, textile fibres.
D. L. Watkins, B.Sc., A.Inst.P., H.N.C., Science Department, Technical College of Monmouthshire, Crosskeys, Mon., U.K.	Emulsions, suspensions, pharma- ceuticals, paints, printing inks, biorheology.