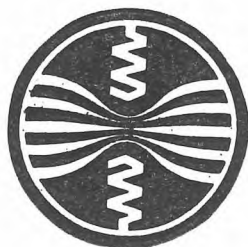


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BULLETIN



BRITISH SOCIETY OF RHEOLOGY

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Hon. Editor:

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FOREWORD

Although the initial excitement over Britain's entry into Europe has now died down, it is perhaps symbolic that the first major meeting of the Society in 1973 is to be held in Europe. This, of course, is the joint meeting with the Dutch Society to be held at Lunteren, the provisional programme for which is given elsewhere in this Bulletin. A good deal of hard work has been done by the organisers of this meeting and it is hoped that their efforts will be amply rewarded by an enthusiastic response.

One of the fears of some people in Britain has been that joining the EEC might lead to a loss of National identity. This could be interpreted in our case as a trend towards a European Society of Rheology several times the size of the BSR. Such a large membership would necessitate many changes in organisation, perhaps involving paid officers with consequently a substantial increase in the subscription rate. The members themselves would need to travel further to meetings which would add to their personal expenses or to their difficulty of getting approval from firms etc. They would also have to cope with language problems, possibly relying on professional interpreters until all the other Europeans learn to speak English (or French?).

All this would radically change the informal "Rheologist Club" atmosphere of the British and other national societies and, in some ways, much of value would be lost. Alternatively, perhaps the various European Societies could enjoy the advantages of closer co-operation, yet still retain their individuality. One could then have the best of both worlds.

COUNCIL 1972-73

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MR. A. V. RAMAMURTHY, c/o Division Chemical Engineering, C.S.I.R.O., P.O. Box 312, Clayton, Victoria 3168.

SOME ADDITIONAL INFORMATION ON THE RHEOLOGY OF "BOUNCING PUTTY".

D. C-H. Cheng and R. W. Higman

Warren Springs Laboratory, Stevenage, Herts.

Recently, in the *Bulletin* Cogswell et al.¹ described the observations they have made on the rheology of "Bouncing Putty." We have also worked on the material and have further data to add.

Our work was carried out on behalf of British Rail as part of their investigation into suspension systems for high-speed freight vehicles, although the material eventually proved to be unsuitable for this application. "Bouncing Putty" has been known for almost three decades but no major use has been found, except as packaging for electronic equipment, in physiotherapy, and as a toy.

The sample we tested was made by Midland Silicones Ltd, and was of grade G9830. Its property was examined over the temperature range from -20°C to $+55^{\circ}\text{C}$ and from 0.5 to 10 Hz, which is equivalent to about a three-and-a-half decade range in reduced frequency.

The oscillatory tests were carried out using a model R15 Weissenberg Rheogoniometer with finely serrated parallel plates to grip the sample. In order to reduce heat conduction into the sample, so as to reach the low temperatures, calibrated tufnol supports were used in place of the usual steel columns. The amplitude and phase measurement were made using variously an UV recorder, an analogue and later a digital electronic transfer function analyser. Details of the calibration and experimental procedure are given in a separate report².

Full details of the results obtained on the "Bouncing Putty" are described in the report². In the present article, we note two important properties, namely thixotropy and temperature-frequency superposition.

Thixotropy (i.e. shear breakdown and rest recovery) in "Bouncing Putty" is apparent even when it is moulded in the hand. During our measurements we found that the torque output signal fell with time in the manner illustrated in Fig. 1. There was a similar change in the phase angle measurement. More extensive investigation at 10°C produced the result shown in Fig. 2.

The curve 113 on Fig. 2 was obtained with a sample from a container holding "Bouncing Putty" which had been tested eight months previously and which had not been disturbed. The curve 115 was obtained on this sample two days later. A second sample from the container gave the curve 213A, but on retesting the same day produced the curve 213B. During these tests, oscillation was continued and readings taken only for such a time as would allow extrapolation

to zero time to be accurately achieved, and for each test the frequency used was gradually increased from the lowest value. It is the extrapolated data which are plotted on Fig. 2.

The curves 214 were obtained with a third sample of "Bouncing Putty" which had been subjected to a standardised pretreatment, described below. The curve 214A represents the extrapolated zero time results; the curve 214B represents the readings obtained after 10 min. of oscillation; and for the curve 214C, the oscillation had been continued for a long time so that steady torque output was attained.

It is clear from these results that "Bouncing Putty" undergoes shear breakdown, but recovers at rest. The effect of the breakdown is increased with frequency and amplitude of oscillation, but a steady state can be reached on prolonged shearing. These descriptions fit that of thixotropy, which means that the testing of "Bouncing Putty" has to be standardised and the interpretation of results done with care.

To investigate the temperature-frequency superposition, we chose the following standard pretreatment. Each sample was moulded by hand into discs of about 3 mm thickness in perspex holders and stored for a few days either at room temperature or in a refrigerator at just below the test temperature. The readings taken were extrapolated to zero time and these results were treated for temperature-frequency superposition by means of the Williams-Landel-Ferry method³. The shift factor a_T was found to obey the WLF-equation

$$\log a_T = \frac{4.25(T - T_0)}{139 + T - T_0}$$

(In our work the temperature T is in $^{\circ}\text{K}$, and we have chosen 10°C . as the reference temperature). The reduced results are plotted in Figs. 3 and 4, which include the zero-time data from Fig. 2 and those of Cogswell et al. suitably reduced, using the a_T of the present work.

It can be seen from Figs. 3 and 4 that the WLF-equation fits the data reasonably well. The data scatter, which is more prominent in Fig. 4, may be safely attributed to the uncertainty that the samples were all at the identical thixotropic structural state. There is general agreement between our results and those of Cogswell et al. It is clear that the discrepancy may be attributed to thixotropy and the fact that different batches of "Bouncing Putty" were involved.

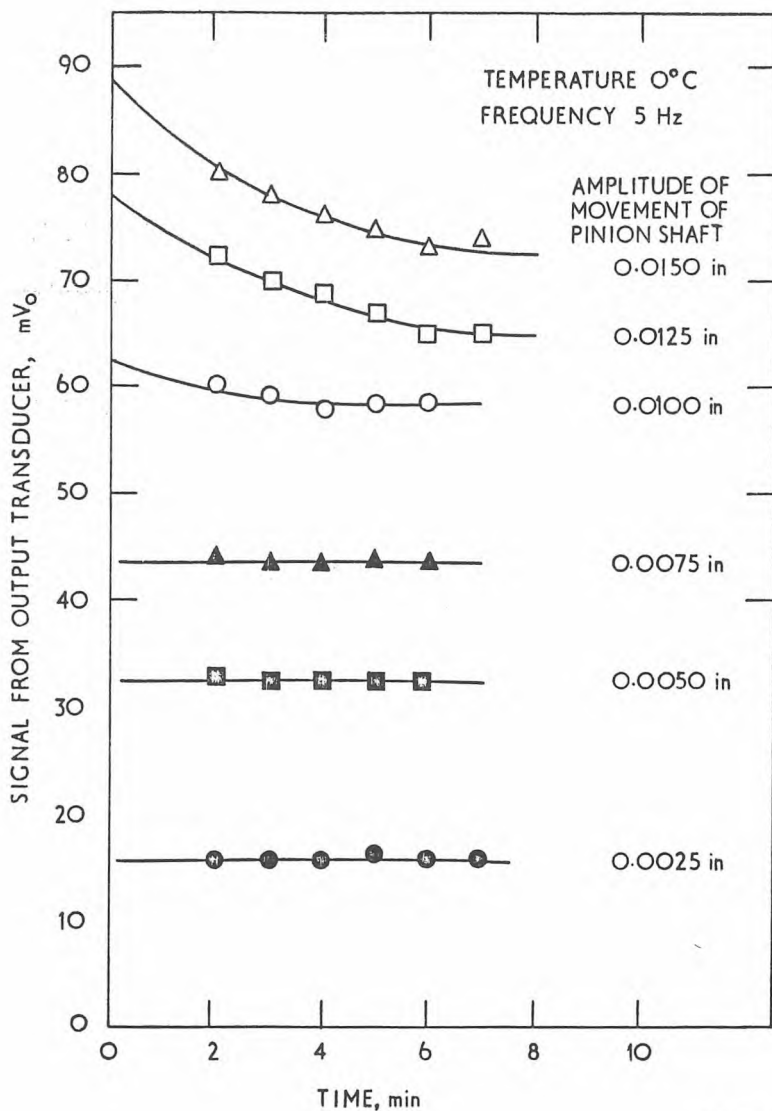
"Bouncing Putty" is a very useful material for demonstrating a wide range of rheological phenomena. It is well known that when left undisturbed, it will flow as a viscous liquid to attain a horizontal surface. When rolled into a ball, it will bounce, like an elastic solid. Dynamic tests show its viscoelasticity, and extrusion tests bring forth die-swell and surface fracture behaviour. When a rod of the material is pulled slowly, it demonstrates ductile fracture, while a sharp tug on

the rod or high impact causes brittle fracture. Our observations indicate that it exhibits recoverable shear breakdown or thixotropy.

We conclude from these observations that the rheology of "Bouncing Putty" is complex and that very strict control over its previous history is required if any measurement is to be accurate and meaningful.

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1. Cogswell, F. N., Gray, J. G. H. and Hubbard, D. A., *Bull. Br. Soc. Rheol.*, 1972, **15**, 29-31.
2. Cheng, D. C-H. and Higman, R. W., *The Use of the Weissenberg Rheogoniometer to Determine the Dynamic Properties of "Bouncing Putty": Some Preliminary Results*. Stevenage: Warren Spring Laboratory, 1971, Res. Rep. LR 166 (MH).
3. Ferry, J. D., *Viscoelastic Properties of Polymers*. New York: Wiley, 1961, pp. 201-47.



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FIG. 1 ILLUSTRATION OF DECREASE OF OUTPUT SIGNAL
WITH TIME

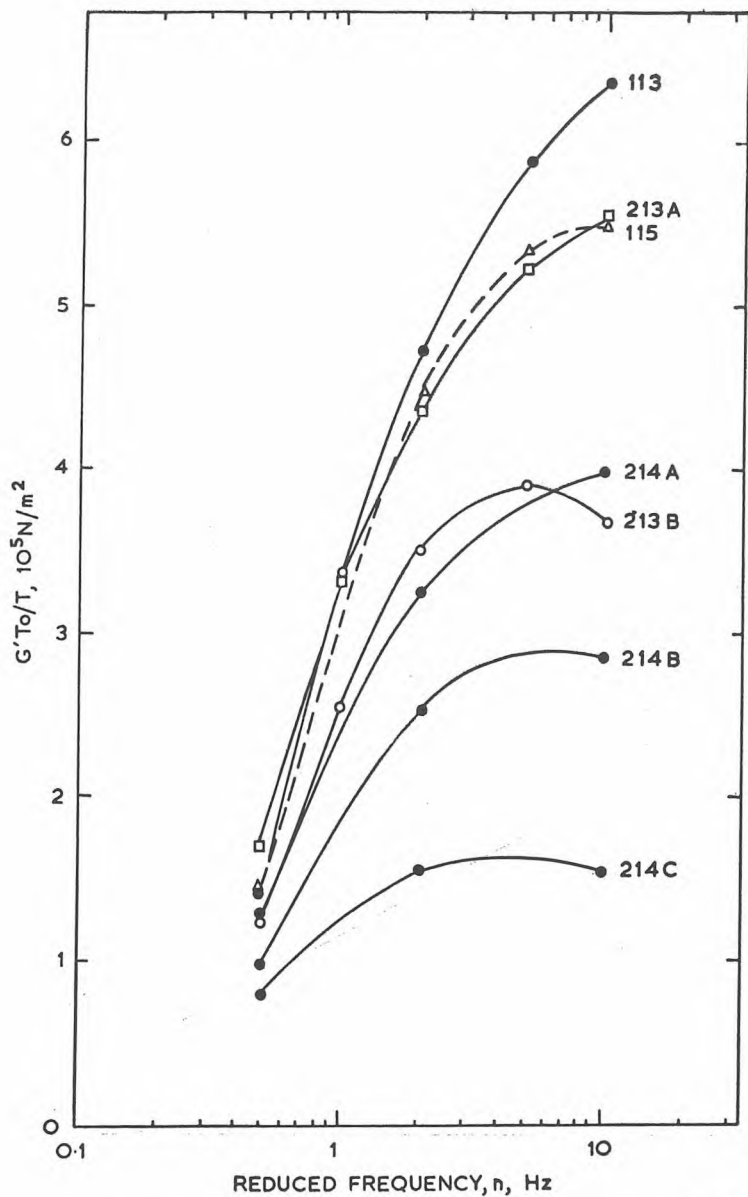
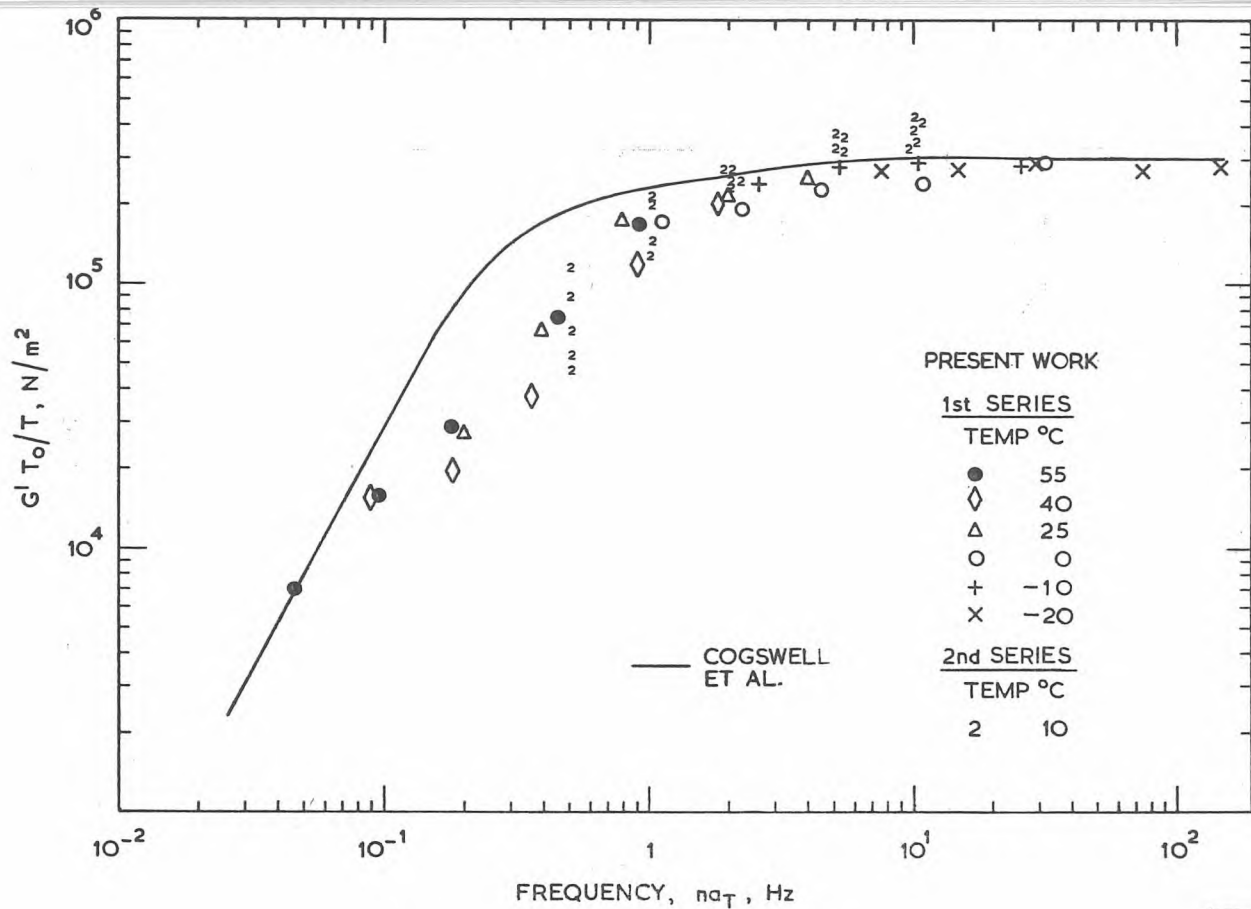


FIG. 2 ILLUSTRATION OF SHEAR BREAKDOWN

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FIG.3 GRAPH OF $G' T_0/T$ AGAINST $n a_T$

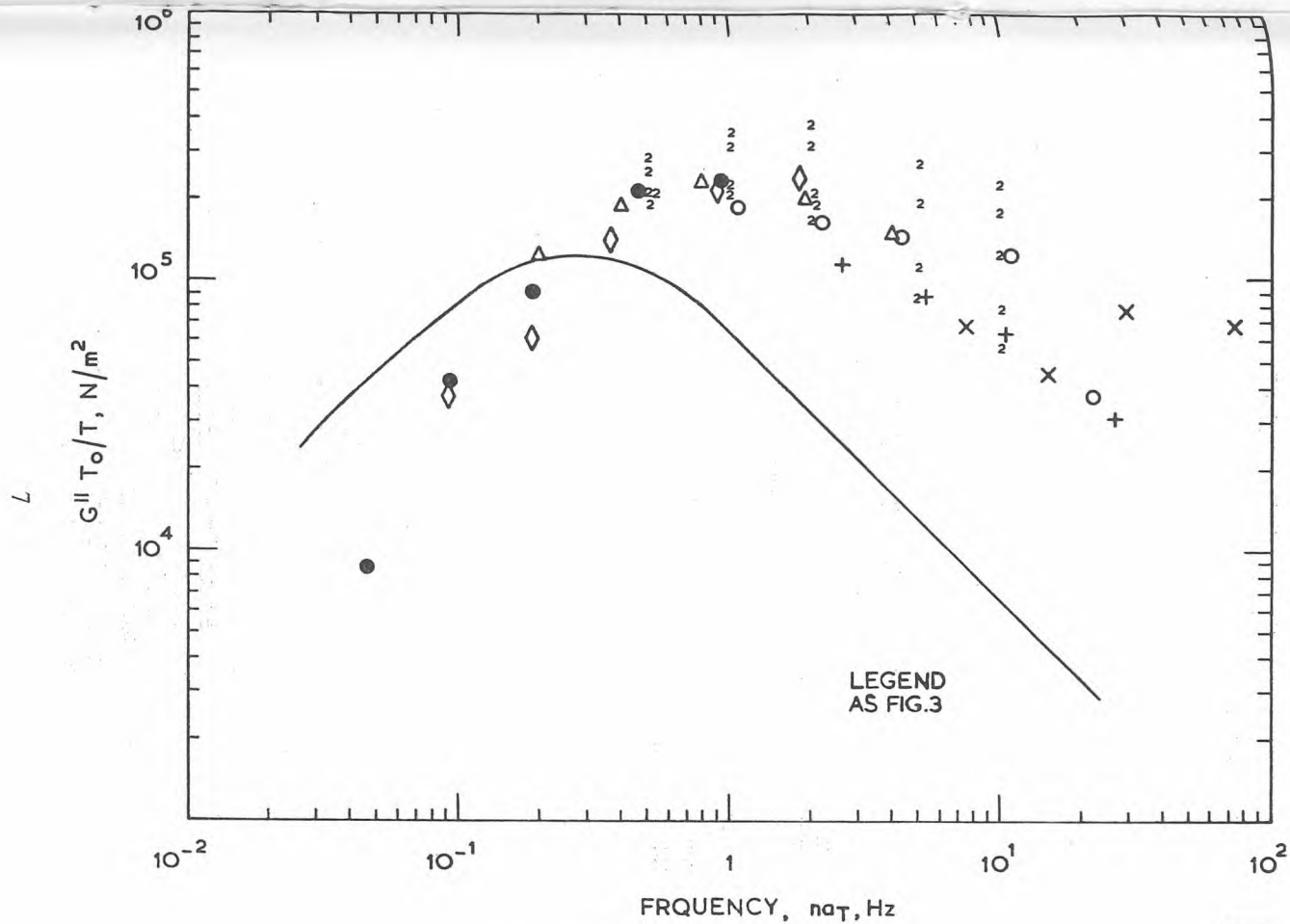


FIG. 4. GRAPH OF $G'' T_o / T$ AGAINST ω

NEW YEAR HONOUR

A former President of the Society, Dr. L. Grunberg, figured in the New Year Honours List when he was awarded the CBE. Dr. Grunberg has completed 22 years in Government Research, in what is now the Department of Trade and Industry, and since 1961 has been Superintendent of Fluids Group at NEL. After a varied career, during which he has written over fifty scientific and technical papers, the time has come for him to relinquish this position. However, he is not giving up research, but will continue without the burden of higher management to interest himself in a number of problems.

WOLFE AWARD

A member of the Society since 1948, Dr. H. Ll. D. Pugh of the National Engineering Laboratory, East Kilbride, has won the Wolfe Award for 1971 for the most outstanding contribution to the research work of the Department of Trade and Industry.

Dr. Pugh's work has led to new production processes capable of producing precision extruded bar of complex cross-section in a wide variety of metals and alloys and the continuous extrusion of fine wire for electronic application.

THE INSTITUTION OF MECHANICAL ENGINEERS AWARD OF FIRST TRIBOLOGY GOLD MEDAL

In September, 1969, the Institution of Mechanical Engineers announced the establishment of a Tribology Trust, the purpose of which was to be the acknowledgement of outstanding achievement and the furthering of interest and study in the new science and technology of friction, wear, lubrication and associated subjects.

The main award is the Tribology Gold Medal, which is awarded at minimum intervals of a year to the person or persons who, in the considered judgement of the Awards Committee, is or are responsible for outstanding contributions to the subject.

In addition, no more than three Silver Medals may be awarded for technical contributions by students and other persons working or researching in the field of tribology and who have not completed their professional education and training.

The fund is administered by the Institution of Mechanical Engineers which has established an Awards Committee under the first

chairmanship of Mr. H. Peter Jost, composed of representatives from:—

The Institution of Mechanical Engineers

The Institution of Production Engineers

The Royal Aeronautical Society

The Department of Trade & Industry.

The first Tribology Gold Medal has been awarded to Dr. David Tabor F.R.S., of Cambridge University for his outstanding contribution in the field of tribology.

Dr. Tabor is the Co-Founder (with the late Professor F. P. Bowden) of the Physical Chemistry Laboratory in Free School Lane, at Cambridge University, which has had a profound influence on the development of the science of tribology throughout the world. Dr. David Tabor has been a member of the Committee on Tribology of the Department of Trade and Industry (formerly the Ministry of Technology) since its inception in 1966 and from 1966–1969 was the Chairman of its Research and Liason Committee.

Notes on the work of Dr. David Tabor, F.R.S.—The Tribology Gold Medallist

There are many today who automatically associate the Laboratory in Free School Lane as the birthplace of the new tribology—the source of the renaissance in our thinking about the behaviour of rubbing solids.

Two figures stand above all others, the late Dr. F. P. Bowden and Dr. David Tabor: two men whose names will inevitably be linked together as the nucleus of a school of thought which has had a profound influence upon the development of the science of tribology throughout the world.

Dr. Tabor joined Dr. Bowden's laboratory just before the last war. His first investigations were largely concerned with establishing the nature of the contact area between contacting solids making use of the electrical conductance techniques pioneered by the late R. Holm. Tabor was able to show that the real area of contact was only a very small fraction of the total available area and that this area was primarily determined by the load applied to the surfaces. This research had an important influence on our thinking and allowed the Coulomb theory of friction to be discarded in favour of the much more attractive theory based upon atomic and molecular adhesion.

Tabor recognised that the real secrets of our understanding of tribological phenomena were not merely resident in the immediate surface atoms, but rather in a surface layer of some depth. The manner in which the contact regions deformed under load was possibly the key to further advances. This involvement with the elastic and plastic properties of the surface zone naturally lead him to think

seriously about the meaning of the hardness and finally culminated in his very successful book on the "Hardness of Metals" in 1951. Much of the work covered by this book was undertaken in Australia where Dr. Bowden and Dr. Tabor established a Tribophysics Division of the CSIRO in Melbourne during the war years. After the war they were invited back to Cambridge to form a group working on the Physics and Chemistry of Rubbing Solids.

In writing his book on "Hardness", Dr. Tabor constantly emphasised the physical concepts involved and has not burdened the text with unnecessary mathematical treatments. This style of presentation has always been adopted by Dr. Tabor throughout his research career and his papers and lectures have won the admiration of all for their simplicity and fluency of text. No-one can have failed to have been impressed by the power of his logic and his ability to express the most complex subject in terms attractive to both specialist and non-specialist alike. His experimental researches have such a masterly level of simplicity and beauty about them that they stand out as classic examples of the power of the scientific method.

Since the war years Dr. Tabor has contributed greatly to the evolution of the adhesion theory of friction. His well-known paper in the *Proc. Roy. Soc.* on the growth of junctions and the control exercised by surface contamination is an example of how he removed one of the major stumbling blocks to the general acceptance of the adhesion theory. However, Dr. Tabor has not restricted his investigations to the behaviour of metals, his researches have encompassed the field of brittle solids, hard elastic solids, lamellar and visco elastic materials. Throughout this work he has constantly attempted to develop a unified picture of the behaviour of these solids; a picture which has not only greatly aided our understanding, but which has been of infinite value in teaching the science of tribology.

Dr. Tabor and Dr. Bowden were primarily responsible for the PTFE type of bearing, a development which has had a tremendous influence on dry bearing design and application. However, one of Dr. Tabor's particular interests has been in the field of rubber and particularly in trying to understand the source of rolling friction. His theory of rolling friction based upon hysteretic losses is now well-known and has led to the development of the modern non-skid motor car tyre (Patent No. 19177).

Although Dr. Tabor has rarely set out to do more than try and understand the behaviour of rubbing surfaces, one has always felt that he has been motivated by the possibility of application of new knowledge to the benefit of industry. The modern dry bearing, whether it contains polymeric material or lamellar solid, the behaviour of bearings in outer space, the formulation of lubricants, the development of impact erosion materials for aircraft, the motor car tyre, all owe a great deal to the work of Dr. Tabor and his colleagues. In fact, Dr.

Tabor's recent work on the behaviour of thin films of liquids between rubber and glass is directly concerned with the problems associated with windscreen vision.

The two books published jointly by Dr. Tabor and Dr. Bowden on the "Friction and Lubrication of Solids" have become the basic texts for all tribologists and very largely contain details of the numerous researches undertaken by the Cambridge School. Although many aspects of tribology have not been investigated fully by these researchers, these books nevertheless contain a remarkable coverage of tribological interests. The scope and depth of the work that has been undertaken undoubtedly marks this School as one of the distinguished in the world and one which has added prestige not only to Cambridge but to Great Britain.

The publications of Dr. Tabor are too numerous to cite. He must be the author or joint author of at least 100 scientific papers, many of which have been published in the Royal Society Proceedings. He has written four books, "The Hardness of Metals", (1951), "Friction and Lubrication of Solids" Part 1 and 11 (1950 and 1964) and "Gases, Liquids and Solids" (1969).

JOINT MEETING WITH THE DUTCH SOCIETY

Joint meeting of the British Society of Rheology and the Nederlandse Reologische Vereniging on 26th and 27th April 1973, at Lunteren, Netherlands.

DRAFT PROGRAMME

Thursday 26th April

10.30 Opening address.

10.45 **J. Heijboer**, Centraal Laboratorium T.N.O. Delft. Physical-mechanical characterization of plastics in view of their application.

11.30 **H. E. van Es**, **H. van Ballegooyen** and **H. A. M. van Eekelen**, Koninklijke-Shell Laboratorium, Amsterdam. A model approach to raw rubber processing.

12.15 **D. L. De Jong**, Koninklijke-Shell Laboratorium, Amsterdam. Viscoelastic analysis of pavement response under moving load.

13.00 Lunch.

14.00 **T. G. Rogers**, Dep. of Theor. Mechanics, University of Nottingham. A simple continuum model for fibre-reinforced materials.

- 14.45 **F. M. Waals**, Koninklijke-Shell Laboratorium, Amsterdam. Stiffness properties of orientated fibre composites and foams.
- 15.30 Tea break.
- 15.45 **K. N. Street**, Centre des Matériaux, Ecole des Mines de Paris, Corbeil Essones. Time dependent flow and rupture properties of metals containing strong fibres.
- 16.30 **J. van Leeuwen**, Kunststoffen en Rubber-Instituut T.N.O. Delft. The view of a plastics technologist on rheology.
- 19.00 Dinner.

Friday 27th April

- 8.00 Breakfast.
- 8.30 **R. I. Tanner**, Div. of Eng. Brown University, Providence R.I. Die-swell reconsidered: some numerical solutions using a finite element model.
- 9.15 **M. F. Edwards and W. L. Wilkinson**, Dep. of Chem. Engin., University of Bradford. Heat transfer to non-Newtonian fluids.
- 10.00 **L. Ronald Whitlock and Roger S. Porter**, Polymer Science and Engineering, University of Massachusetts, Amherst Mass. The source of degradation during extrusion of polystyrene.
- 10.45 Coffee break.
- 11.00 **A. B. Metzner**, University of Delaware, Newark Del., U.S.A. The contrasting behaviour of dilute solutions (as compared to molten polymers) in extensional flow fibre spinning experiments.
- 11.45 **F. N. Cogswell and D. C. F. Couzens**, I.C.I. Ltd. Plastics Div., Welwyn Garden City. The extrusion coating process—a rheological study.
- 12.30 Lunch.
- 13.30 **B. Yates**, Unilever Research Laboratory, Port Sunlight. The rheology of mixed surfactant systems.
- 14.15 **M. van den Tempel**, Unilever Research Laboratorium, Vlaardingen. Rheology of fluid interfaces.
- 15.00 Tea break.
- 15.15 **J. Mewis**, Kath. University Leuven, and **A. B. Metzner**, University of Delaware, Newark. Extensional flow properties of fibres suspended in Newtonian fluids.
- 16.00 **A. F. Johnson and F. J. Lockett**, National Phys. Lab. Teddington. Flow of polymer melts containing chopped fibres.
- 16.30 Closing address.

DIARY

1973

9-13 April. Postgraduate School in Rheology. School of Pharmacy, University of London.

26-27 April. Joint Meeting with the Dutch Society: "Composites" and "Rheology in Industry". To be held near Utrecht.

7-11 May. SPE/PI joint conference, Montreal.

10-12 May. 2nd meeting Italian Society of Rheology.

18-20 June. Conference: Plastics Industries in the Developing World (Plastics Institute).

28-29 June. The Chemistry and Physics of Fibres and Filaments (UMIST).

10-14 September. IUPAC International Symposium on Macromolecules. Aberdeen.

18-21 September. BSR Autumn Meeting, East Anglia University, Norwich.

WE WOULD LIKE TO HEAR FROM YOU

B.S.R. members are reminded that the Editor of the *Bulletin* is always interested in receiving informative articles, comments, news and other material which would help to make the *Bulletin* one of the more welcome sights in the flood of reading matter to which most of us are accustomed and resigned.

Suggestions of possible improvements in the *Bulletin* would also be welcome. So if you have a thought and a minute to put pen to paper why not let us hear about it?