

gash
(my paper)

THE
BRITISH SOCIETY
OF RHEOLOGY

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Hon. Secretary :

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Waldegrave Road,
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Rheology in Dairying

by G. W. SCOTT BLAIR,

National Institute for Research in Dairying, University of Reading

The subject falls naturally into two parts: first, the rheology of milk and its products, such as cream, butter and cheese and secondly the rheology of body fluids of the bull and cow in relation to fertility and hence, indirectly, to milk production.

Starting with milk and milk products, there are two main applications for rheological testing. The first concerns processes of manufacture; e.g. milk is continually caused to flow in bulk, butters are blended and must not only mix adequately but must not stick unduly to the mixing machinery; cheese must have the right rheological properties at each stage in its manufacture (including ripening) otherwise the wrong kinds of micro-organisms may develop and produce bad flavours and odours. Secondly, the finished product must have an acceptable consistency for household or commercial use, e.g. butter must not change its "spreadability" too markedly with changes in temperature; cream having a standardised fat content must be neither a solid mass which fails to come out of the container nor be so thin that the housewife cannot believe that it is sufficiently rich in fat; there are certain standards for the "crumbliness" of cheese depending, for example, on whether it is a Cheddar or a Cheshire. The housewife's tastes also differ in different parts of the country.

Although many papers have been published on the viscosity of milk (a good summary is given by Cox, Hosking and Posener, 1959, and little has been done since then) practical applications have been rare, chiefly because in most of the processes in which milk flows through pasteurisers, coolers and other machines, the flow is turbulent. There are, of course, partial correlations with chemical composition (fat and solid-not-fat) but viscosity measurements do not provide an accurate method for such analyses.

Milk is almost a Newtonian liquid but, as soon as the fat content is increased by centrifuging or settling, the cream starts to show anomalous behaviour. Two creams, even if made from the same milk, and having the same fat content, may differ very widely in consistency depending on the clumping together of the fat globules. It is known in the trade more or less how to control these conditions by means of temperature treatments. The subject is well summarised by Crossley and Rothwell (1954) and Crossley (1955). Long ago, the present writer made an intensive study of cream in a capillary viscometer and found almost every (then) known rheological anomaly (Scott Blair, Hening and Wagstaff, 1939). Very little fundamental work has been done since, until J. H. Prentice's recent studies at the N.I.R.D., using a concentric cylinder viscometer, the results of which are as yet

unpublished; but it is clear that by working at very low and constant rates of shear a very much simpler picture can be obtained.

Work on butter and cheese is fully summarised in a book by Baron (1952). Several chapters in a book edited by the present writer (Scott Blair, 1953) summarise work on rheology of dairy products in general but considerable further work has, of course, been done since these dates.

It is generally said that cream, an emulsion of fat in an aqueous phase, is "inverted" by churning into butter, which has a continuous fat phase with aqueous dispersed droplets. This cannot be precisely true since Prentice (1953) has shown that butter conducts electricity and indeed that the electrical resistance provides a useful practical test of keeping quality, since the corridors of liquid which must run through the butter permit the passage of harmful micro-organisms, of proteins and of air.

Much work has been done on the microscopic examination of fat clusters in butter and on *ad hoc* methods for measuring its consistency; but most of this work has rather naturally been carried out in countries which, unlike our own, make large quantities of butter. Prentice, however, has subjected butters to many of the well-known types of rheological test and compared the data, using Multiple Factor Analysis, with the statistically massed judgements of housewives. It seemed that a simple orifice viscometer which records the force needed to maintain a constant rate of extrusion gives a very high correlation indeed with the housewife's concept of "spreadability", at least in the Reading area (Prentice, 1954). Work is also in progress at the N.I.R.D. to try to find out why certain pairs of butters blend so much more easily than others.

On the borderline of rheology is work concerning the "hesion" of butters. (The term "hesion", analogous to "sorption", includes both cohesion and adhesion.) Claassens (1958, 1959) studied these properties by two methods: withdrawing a standard weight which had rested on a carefully prepared surface of butter for a fixed time; and tilting a platform on which a weight rested on a butter surface until it just began to slide. Hesion was found to be highly dependent on the nature of the surface in contact with the butter.

By far the greatest volume of published work in dairy rheology is concerned with cheese. This is because the "body" of cheese, as it is called, controls to a considerable extent the processes of ripening and, as has already been stated, the development of the preponderant microbiological flora. Although the composition of the milk has some effect, the essential differences between the different types of cheese depend on the processes of manufacture and especially on the control of acidity and consistency at each stage. The latter is normally judged by the subjective assessment of the cheese-maker handling the curd. Such judgements can, of course, be replaced by rheological

tests but so far the industry has been slow to use those available. It seems likely that, in the fairly near future, the whole process of, at any rate hard cheese-making, will be rationalised and greatly speeded up by the introduction of mechanical processes. If drastic changes are made, no doubt rheological tests will come into their own.

The earlier work, described in Miss Baron's book (*loc. cit*) together with some more recent developments will be briefly described here.

It is clear that, to be useful, the results of rheological tests must correlate with the subjective judgements of the experts and this involves psycho-physical problems. A very thorough study of what people can and do "feel" when they squeeze materials like cheese between the fingers is given in a Monograph by Harper (1952). It is clearly essential that rheological and psychological studies must be made concurrently if any useful tests are to be devised. Joint work of this kind led the present writer to propose what he called an "integrative" approach to rheology which is discussed fully in two books (Scott Blair, 1949, 1950) and will not be dealt with here.

In the making of hard cheese (e.g. Cheddar, Cheshire, Caerphilly, Gruyère, Dutch, etc.) milk, brought to the correct acidity and temperature, is inoculated with a "starter" or bacteriologically active preparation; and with rennet, which consists mainly of an enzyme, rennin, which coagulates the milk into a junket ("curd"). When a certain degree of "firmness" of the curd is reached, it is cut into small pieces by means of (usually mechanically operated) "knives". Several methods have been proposed for following this "firming up" process and determining the point at which the curd should be cut. Originally, a small weight was lowered on to a light tray resting on the surface and the displacement was measured. Later, a graduated plastic bowl was laid on the curd, and the depth of penetration measured after a specified time but the method was not sufficiently accurate. Moreover, both these methods were affected by cooling on the surface of the curd. Recently, a torsionmeter, modified from an instrument designed to test rubber latex, has been found very effective. This has the advantage that the consistency is measured well below the surface of the milk, when the temperature is less liable to fluctuation. The cylinder is caused to oscillate through a small angle and the torque on a spring required to produce this constant strain at an approximately constant rate, is recorded. It must be stressed, however, that such instruments do not *replace* the skill of the cheese-maker, since all curds are not to be cut at the same firmness; rather they serve to help the cheese-maker as clinical thermometers and sphygmomanometers help the physician in making a diagnosis. No doctor today would be without these aids but medical skill and experience is still required for their proper use and interpretation.

After the curd has been cut into small pieces and much of the

whey released from it, the curds and whey are stirred. The temperature is then raised and the grains contract and harden by a process of syneresis. The cheese-maker takes a handful of the grains of curd and, by squeezing, he judges their dryness by their firmness and so determines when to stop this process and let the curd settle to the bottom of the vat, before its separation from the whey. (Again, acidity is measured and he takes account of this in making his judgement.) Direct rheological measurements at this stage have so far proved impossible but, by casting a small cylinder of curd of fixed diameter and measuring its weight and height and hence calculating the superficial density, a method has been developed which measures the extent to which whey has been replaced by air, and hence the degree of syneresis is determined.

After the whey is withdrawn, the curd, which now has approximately the consistency of crêpe rubber, is collected and cut into blocks which are turned and stacked along the sides of the vat to encourage drainage of the whey. Until very recently, when more rational methods have been tried, the continuous draining process ("Cheddaring") went on for a very long time, about $1\frac{1}{2}$ -2 hours. Finally, in making cheese of the Cheddar-Cheshire type, the blocks are cut in a mill into pieces about the size of a finger and mixed with salt. These pieces are packed carefully into a mould, which may be cylindrical or rectangular in shape, and submitted to a high pressure, in a gang press at some three tons for about 24 hours. After this, the young cheese ("green cheese") is ripened in a room at constant humidity and temperature. At a certain age (two weeks for Cheshire and four weeks for Cheddar) it is judged by a grader for quality. "Firmness" and "springiness" play an important part in his judgement. These properties are easily measured by the rheologist using a fairly heavy sphere-hardness tester but at least two tests must be made on each end of the cheese (which is never completely homogeneous) and the whole process takes about five minutes per cheese. This, together with the weight of the apparatus, proves a practical disadvantage. Micro-hardness testers have so far not proved satisfactory partly because of the uneven surface of the cheese, even if a small piece of the bandage or other covering is removed. Something as quick and simple as an ordinary motor tyre gauge is badly needed but, apart from heterogeneity, it must be remembered that cheese is elasto-viscous so that some timing device must be incorporated.

Although these instruments are but little used in the industry, rheological data obtained at each available stage in cheese making have shown a remarkably consistent picture and differences in the course of manufacture using, for example, a good and a poor milk, can be followed, and have been shown to be consistent and meaningful.

The second important aspect of dairy science is its connection with problems of animal breeding. Most cows are now inseminated artifi-

cially and the process is at least as satisfactory as natural mating; nevertheless it is known that there are, in both cases, too many instances when conception is interrupted and a foetus is lost, usually at an early stage of pregnancy. Pregnancy in the cow cannot be detected by the usual hormone tests, so effective with human beings, even if blood is used in place of urine; and the first indication that the veterinarian can give is when, usually about 40 days after conception, he can feel the foetal membranes with his hand, *per rectum*. For research, if not for practical purposes, an earlier test is of value, even if the reliability is not as high as that of the hormone tests for humans. Moreover, a cow can only be successfully mated or inseminated during a short period ("heat" or oestrus) which occurs once every three weeks. It is usually possible to detect this condition by observing the behaviour of the cow but, especially under extreme conditions of heat or cold, the hormone levels are low and "signs of heat" are almost, if not totally absent. Oestrus is, therefore, often missed under these conditions.

In the narrow passageway between the uterus (womb) and the vagina of the cow and of most other mammals (known as the "cervix"), there is produced a slimy mucous secretion. The purpose of this is not fully understood but it may help the sperm to find its way to the ovum. It has long been known that at about the time of the release of the ovum ("ovulation"), which, in the cow closely follows oestrus, this mucus not only increases greatly in quantity and fluidity but also becomes highly flow-elastic. This flow-elasticity is easily measured by extruding mucus from a narrow glass tube, removing the pressure, and following the elastic recoil. (For an early review of this work see Scott Blair, 1952.) A very simple instrument called, rather inaccurately "the Oestroscope", is commercially available for this purpose.

When the cow becomes pregnant, there is no flow-elasticity and the mucus gradually increases in consistency, at least during the greater part of pregnancy. Many attempts were made to measure this consistency as an indication of pregnancy. There were two main difficulties: first only very small samples are available and these must be taken with extreme care from the mouth of the cervix if the cow is not to be damaged. Secondly, there is a stage in the normal cycle, furthest removed from oestrus, when the consistency of the mucus can be quite high and this is even more true in certain pathological conditions. After many preliminary attempts, Scott Blair and Glover (1957) were able to report experiments using an emptying capillary viscometer (available commercially as "the Consistometer") and, excluding any cows with pathological conditions in the genital tract, 92 per cent of pregnant cows were correctly diagnosed 28 days after conception. Quite a high percentage of cows which had been inseminated were found pregnant at 28 days but both a veterinary examination and the rheological test showed a negative result at about 40 days. These cases are believed to be due to lost foetuses.

Since the farmer is more anxious to know whether his cow is likely to come to calf than whether she is pregnant at 28 days, and since the taking of the samples is almost as skilled a technique as is rectal palpation, the test has not found much practical application; but it is being used for research purposes for the study of the causes of early foetal losses, especially in Israel. In that country, and also in Lithuania, work is in progress on the relationships between other physiological conditions and the rheology of cervical mucus.

The part played by the bull must be considered in relation to fertility. Preliminary work by Szumowski (1948) has shown that there are correlations between the viscosity of bull semen and its quality as assessed in various ways. A paper would have been presented by the present writer with his colleague, Mr. F. A. Glover, describing further developments in this field at the autumn meeting (1965) of the British Society of Rheology.

Notes. Readers wanting further detailed information on dairy science, including rheology, are advised to consult J. G. Davis' "Dictionary of Dairying" (1955). The Oestroscope and the Consistometer are obtainable from Messrs. Arnold & Son, 54 Wigmore Street, London W.1.

I am much indebted to Miss Helen Chapman, Head of the Dairy at N.I.R.D., for helping me in writing the section which concerns cheese making and other dairy processes.

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Letter to the Editor

Dear Sir,

In his Presidential Address (Bulletin, 1965, No. 1) Dr. Roscoe advocates (p. 9) the carrying out of measurements of the temperature variation of viscosity of liquids at constant volume in order to determine a "true" activation energy of viscous flow. In fact such studies have been made by Dr. A. S. C. Lawrence (now of Sheffield University) and me^{1, 2, 3} using both a direct experimental technique and calculations combining existing viscosity-temperature-pressure and density-temperature-pressure data.

We were able to show that, for many simple organic liquids, the fall of viscosity with increasing temperature is very much smaller at constant volume than at constant pressure, so that the latter is largely due to thermal expansion of the liquid lattice, i.e. a volume effect. (Several major theories of liquid viscosity start from the premise that it is primarily a temperature effect with the volume correction a secondary factor.) We also calculated the activation energy of viscous flow at constant volume as a function of volume for a number of liquids and discussed its significance.

A concise account of the theoretical aspects of viscous flow at constant volume and constant pressure has been given by Moelwyn-Hughes.⁴

Yours faithfully,

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British Glues and Chemicals Ltd.,
153 New Bedford Road,
Luton, Beds.

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- ⁴ Moelwyn-Hughes, E. A., "Physical Chemistry," 2nd revised edition, 1961, pp. 715-720 (Pergamon Press).

Rheology in Australia

The Polymer Division of the Royal Australian Chemical Institute and the Victorian branch of the British Society of Rheology held a joint meeting on April 9th on the subject of "The Processing of Thermoplastics". Over 70 members and visitors attended the meeting, which was held at I.C.I. House, Melbourne.

The meeting began with a paper by Dr. R. E. Price (I.C.I.A.N.Z.) entitled "The use of laboratory measurements in extruder design and operation". Available equipment was described, types of possible measurements discussed, and the extent of use of small scale techniques considered. This paper was then followed by one on "Commercial extruders", given by D. Bowers (Telford Smith).

"Factors affecting quality in polyethylene extrusion" were discussed by T. A. Velkou (Union Carbide Australia). Quality was divided into the categories of (i) dimensional, and (ii) mechanical homogeneity, both extruder design and operating variables being considered.

B. C. Loft (I.C.I.A.N.Z.) spoke on the "Heat sealing of thermoplastic films". Surface seals, which form instantaneously at low temperatures, delaminate under stress, and behave according to the adsorption theory of adhesion. Fusion seals, formed at higher temperatures, are as strong as the base material, and behave according to diffusion theory. Best sealability is obtained using films of low crystallinity and high melt viscosity.

The final paper, on "Pressure sensitive adhesives" was given by L. R. Fortune (Sellotape). The function of resins in natural rubber—resin pressure sensitive adhesives was discussed. Tack reached a maximum, after which further increase in resin concentration caused it to drop sharply. Electron microscope studies indicated a "second phase" in the rubber-resin system when the system was tacky.

The New South Wales branch of the society, in co-operation with the Victorian branch, held an exhibition of "Original Rheological Instrumentation" and a symposium on "Rheological Measurements" at Sydney University, June 1st and 2nd. The objects were to encourage interchange of information on rheology and rheological measurements, to introduce new workers to a diversity of techniques, and to develop new concepts. Commercial instruments were not admitted, and the symposium was planned around the instruments exhibited.

Papers presented on June 1st were grouped under the heading of "Fluids". Capillary and rotational viscometers and their applications were discussed, in addition to a session on "viscoelasticity and normal stress".

The following day was devoted to "Solids". Topics discussed included tensile strength, creep, yield values, viscoelasticity and biaxial strain.

Rheological Terminology in France

At its meeting on May 20th, 1965, the Council of Groupe Français de Rhéologie adopted 20 definitions of rheological terms. Further definitions will be considered later.

A literal translation of the terms into English is given below. Phrases in parentheses are what the Groupe considers to be English equivalents.

1. *Facette*.

This term designates an infinitely small surface element considered as belonging to a portion of matter which it limits. One calls "*normale extérieure à la facette*" the normal directed towards the exterior of the portion of matter considered.

2. *Contrainte* (stress).

The contact force exerted on a *facette*, relative to the area of that *facette*.

3. *Etat de contrainte* (state of stress).

The system of stresses exerted on the different *facettes* about a point. This system may be represented by a tensor called *tenseur des contraintes* (stress tensor).

4. *Sollicitation mécanique* (system of loads).

The system of external forces giving rise to stresses.

5. *Contrainte normale* (normal stress).

The projection of the stress applied to a *facette* along the normal to that *facette*.

6. *Tension* (tension).

The normal stress in the same sense as the external normal to the *facette*.

7. *Pression* (pressure).

The normal stress in the opposite sense to the external normal to the *facette*.

8. *Cission* or *Contrainte tangentielle* (shear stress).

The projection of the applied stress to a *facette* in the plane of that *facette*.

9. *Déformation* (strain).

The modification of mutual distances between different points in a body.

10. *Dilatation* (strain).

The relative variation, considered algebraically, of the distance between two points. A *contraction* is a negative strain.

11a. *Distorsion* (angle of shear).

The change is the angle formed between two lines having the same origin, which were perpendicular before deformation. Called also *glissement* (see 13c).

11b. *Distorsion* (constant volume deformation).

The term is sometimes used in the sense of deformation with no change of volume. It is advisable to use instead the term *déformation isochore*.

12. *Etate de déformation* (state of strain).

The system of *dilations* and *distorsions* about a point. The system may be represented by a tensor called *tenseur des déformations*.

13. *Glissement*.

(a) (Slip).

A relative displacement of two bodies, or two parts of a body separated by a surface, such that the two bodies, or two parts, remain in contact. If the surface is a plane, the relative displacement is parallel to the plane.

(b) (Shear strain).

A strain in which the displacement in the neighbourhood of a point is continuous, parallel to a fixed direction, and proportional to the distance from a fixed plane containing that direction. Called also *déformation de cisaillement*.

(c) (Angle of shear).

The change in the angle formed between two lines having the same origin, which were perpendicular before deformation.

The term is a less preferred alternative to 11a *distorsion*.

14. *Cisaillement*.

The term is generally used in the sense of *contrainte tangentielle* (cf. 8), but sometimes also in the sense of *déformation par glissement continu* (cf. 13b). Consequently it is recommended that one specifies precisely either *contrainte de cisaillement* (*cission*) or *déformation de cisaillement* (*glissement continu*).

15. *Instantané* (instantaneous).

That which takes place in a time less than the response time of the experimental set-up (*appareillage*) considered.

16. *Différé* (delayed).

That which takes place in a time greater than the response time of the set-up considered (Fr. "*après écoulement du temps de réponse*").

17. *Elasticité* (elasticity).

The tendency for a body to recover the form and dimensions which it had before loading, when the load is removed.

18. *Recouvrance* (recovery).

The reduction in deformation after unloading. *Recouvrance globale* is the sum of *recouvrances instantanée* and *différée*.

19. *Déformation résiduelle au temps t* (residual deformation).

The deformation remaining at time *t* after removal of the load.

20. *Déformation permanente* (permanent deformation).

The limit towards which *déformation résiduelle* tends at infinite time.

Any comments regarding the above definitions should be sent to:

M. B. Persoz,
Groupe Français de Rhéologie,
68 Boulevard St. Michel,
Paris 6.

[The term *facette* is one for which an English equivalent would be useful. Dr. G. W. Scott Blair makes the following comments.

"I have thought about a special use of the word 'facet' for this term, but Hugh Johns suggests that it might confuse crystallographer-rheologists. Johns suggests 'a miniscule'. I wonder if 'minisculum' would not sound better (Latin *minisculus*, a rather small part of). The old English word 'whit' (Oxford Dictionary a very small, or the least, portion or amount; a particle) is pretty exact!"]

Any Problems?

The Research Committee would be interested to learn about problems with which the members of the society are wrestling.

If you have a difficult problem on your hands, you would be doing a service, certainly to the Society and possibly to yourself, by writing to the Secretary of the Research Committee about it at the address below. Your letter will be copied and sent to every member of the Committee, who will study it from two points of view.

First, it may prove possible to make some suggestions about your problem, or to recommend possible sources of information. If the Committee is able to help in this way, or by answering specific questions put by members, it will be glad to do so.

Secondly, your letter will provide the Research Committee with valuable information. We are trying to compile a list of unsolved rheological problems, and to assess the importance of each problem (1) to the advancement of rheological knowledge, and (2) to industry. When complete, this list will help us to pinpoint the areas where rheological research is most likely to prove fruitful.

But we need your help before we can hope to make the list anything like complete. Please don't leave it to the other fellow to write and tell us of that "very obvious" problem you know about—he almost certainly intends to leave it to you!

A. T. J. HAYWARD.
*Secretary to the British Society
of Rheology Research Committee.*

National Engineering Laboratory,
East Kilbride, Glasgow.

Notes and News

The Engineering Institution's Joint Council set up in 1962 as a federation of 13 Chartered Engineering Institutions, has now been granted a Royal Charter, and will in future be known as the Council of Engineering Institutions. The Duke of Edinburgh has agreed to become its Founder President for a period of five years.

The President of the Society of Rheology (U.S.A.), James T. Bergen, of Armstrong Cork Co., Lancaster, Pa., has been authorised as an official representative of the Society to the British Society of Rheology.

The Research Committee of the Institution of Chemical Engineers has been studying a report on "The mixing of powders, pastes and non-Newtonian fluids", prepared by Dr. J. R. Bourne of Nottingham University. The Committee considers it desirable that research work in the field of mixing be co-ordinated to the extent of interchange of information between research workers, and between these workers and certain equipment manufacturers and users. To this end a working party is being established by the Institution. The Chairman is Dr. F. H. H. Valentin, and the Honorary Secretary Dr. J. R. Bourne. A Steering Committee is being formed to define the specific terms of reference prior to the formation of the working party as a whole.

Enquiries for further information should be addressed to:

Dr. F. H. H. Valentin,
Warren Spring Laboratory,
Gunnels Wood Road,
Stevenage, Herts.

Conferences and Symposia

The British Society of Rheology and the Colloid and Surface Chemistry Group of the Society of Chemical Industry are to hold a joint symposium on "The Chemistry and Rheology of Water Soluble Gums and Colloids".

The meeting will be held on March 28th, 1966, at the School of Pharmacy, London University. Papers to be presented include:

"Alginates and their derivatives", by R. H. McDowell.

"Preparation and study of the specific carrageenins", by Dr. H. Kragen.

"Some special characteristics of cellulose ethers", by Dr. J. Ogg.

"Relationship of chemical structure of cellulose ethers to physical properties", by A. J. Desmarais and H. O. Esser.

"The physical properties of synovial fluid", by Prof. D. N. Davies.

- "The rheology of deoxyribosenucleic acid", by Dr. A. B. Robins.
- "Studies on polyvinyl pyrrolidone in relation to protein interactions in solution", by Dr. P. Molyneux.
- "Solute-solute interactions in more concentrated solutions of polar polymers", by Dr. A. Packter.
- "The rheology of the ternary system SCMC/glycerin/water", by Dr. M. Nearn.
- "The rheology and physical chemistry of some acacia systems", by B. Warburton.

Further information may be obtained from:

Mr. B. Warburton

Dept. of Pharmaceutics School of Pharmacy,
University of London, 29/39 Brunswick Square,
London, W.C.1.

A symposium on "Mechanism of Viscoelastic Fluids" will be held during the meeting of the American Institute of Chemical Engineers, at Philadelphia, Pennsylvania, December 5th-9th, 1965. Further details from:

A. B. Metzner,
Dept. of Chem. Eng.,
University of Delaware,
Newark, Delaware, U.S.A.

The Fifth U.S. National Congress of Applied Mechanics will be held at the University of Minnesota, Minneapolis, Minn., U.S.A., June 14th-17th, 1966. The Secretary of the Congress, from whom further information may be obtained, is R. Plunkett, 107 Aero Building, University of Minnesota, Minneapolis.

A symposium on "Defects in Glass" will be held in Tokyo and Kyoto, Japan, September 12th-17th, 1966, under the auspices of the International Commission on Glass, in co-operation with the Ceramic Association of Japan. Enquiries should be addressed to:

Prof. M. Imaoka,
Institute of Industrial Science, Tokyo University,
10 Shinryudo-cho, Minato-ku,
Tokyo, Japan.

A wide range of applications and developments of newer engineering materials will be discussed in a symposium to be presented by the Inst. of Mech. Engrs. at Birmingham C.A.T. on October 13th-14th, 1965.

The Hydraulic Plant and Machinery Group of the Institution is holding a symposium entitled "Surges in Pipelines" in London, November 2nd-3rd, 1965. Papers will deal with the significance of surge diagrams, the velocity of waterhammer waves, waterhammer effects due to branched stopped pipes, effects of valve operation and computer solutions of surge problems.

Information on both the above meetings from: Conference Dept., Inst. of Mech. Engrs., 1 Birdcage Walk, London S.W.1.

The Institution will be holding the following meetings of interest to rheologists during 1966.

March 15th-16th—The Planning of Mechanical Engineering Depts. in Universities and Colleges of Technology; London.

April 4th-6th—Applied Mechanics; Cambridge.

April 13th-15th—Thermodynamics and Fluid Mechanics; Liverpool.

May (two days)—Marine Applications of Fluid Power; East Kilbride.

May 12th-14th—(4th) Lubrication and Wear; Scheveningen (Holland).

August 8th-12th—(3rd) International Heat Transfer; Chicago (U.S.A.).

September 14th-16th—Vibrations in Hydraulic Pumps and Turbines; Manchester.

September 23rd—Lubrication in Animal Joints—Natural and Artificial; London.

September 23rd—Lubrication and Wear; Nottingham.

Autumn—Lubrication in the Textile Industry.

The Institute of Physics and the Physical Society announce the following meetings:

"Solid State Physics", to be held at Manchester, January 4th-7th, 1966. Intending authors should send abstracts of papers to Prof. S. F. Edwards, Dept. of Physics, The University, Manchester 13, before November 12th.

"Physical Basis of Yield and Fracture", to be held at Oxford, September 28th-30th 1966. Outlines of papers (300 words) should be sent, by December 1st, 1965, to Dr. W. A. Sammons, Smith & Nephew Research Ltd., Gilstan Park, Harlow, Essex.

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- M. J. BLOGG, B.Sc.(Tech.), Dip.Chem.Eng., A.M.C.T.
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- P. S. STEWART, B.Sc.
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