

THE
BRITISH SOCIETY
OF RHEOLOGY

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Hon. Secretary :

DR. M. F. CULPIN,
8 The Broadway,
Pontypool,
Monmouthshire.

Hon. Editor (Bulletin) :

MR. P. E. KNAPP,
20 Wayside Avenue,
Harrogate,
Yorkshire.

SOME QUERIES

ARISING ON WRITING UP A STANDARD METHOD OF MEASURING THE COEFFICIENT OF VISCOSITY

The object of this article is to ask for help from our members in clearing up some difficulties, mainly about definitions, that arise when Standards are revised or rewritten. The introductory clauses of a Standard Method include definitions, terms used, names of units, etc. so a good "dictionary" description is required for the property of a liquid known generally as viscosity, followed by a note in which technical terms (Newtonian flow, shear stress, etc.) may be used indicating the method used in calculating the result. The following is quoted from British Standard 188, revised 1937, now superseded:—"the viscosity of a fluid is that property to which is due the internal resistance offered to the motion of any portion of that fluid with a velocity different from that of a contiguous portion . . . the dynamic viscosity of a fluid is the tangential force on unit area of either of two parallel planes at unit distance apart when the space between the planes is filled with the fluid in question and one of the planes moves with unit velocity in its own plane relatively to the other." True enough, but this particular Standard used for calculating viscosity, Poiseuille's law of flow with a correction for kinetic energy. The present British Standard indicates the use of the simple equation where the required result is the product of the flow time in seconds and the calibration constant of the viscometer based on the agreed value of the viscosity of water at 20°C. A good general, and a technical definition covering this last general procedure are required.

Two viscosities are described, after Clerk Maxwell, the dynamic viscosity (symbol η) and the kinetic (symbol ν) although the latter has the dimensions of a diffusion coefficient, $\eta/\rho = \nu$ (ρ = density), i.e. $\text{M L}^{-1} \text{T}^{-1} / \text{M L}^{-3} = \text{L}^2 \text{T}^{-1}$.

Dr. L. R. G. Treloar in presenting the B.S.R's committee report on the meaning and use of some rheological terms at the Oxford Conference 1946, pointed out the importance in hydrodynamical reasoning of the ratio of the Newtonian coefficient of viscosity to density, the balance of frictional forces to inertial forces, and recommended that the long-established term "kinematic viscosity" for ν ($= \eta/\rho$) should be retained. The dilemma remains however that Newton's viscosity coefficient η of his well-known assumption $\tau = \eta D$, which equation forms the basis of rheological classification, is designated the dynamic and sometimes absolute viscosity which might imply that η is not unique.

The first query is, should not η be called simply the coefficient of viscosity (abbreviated to viscosity) and the adjectives, dynamic or absolute be discontinued. The use of "absolute" is presumably to indicate that the viscosity is expressed in c.g.s. units and this would also

account for the unfortunate expression "absolute kinematic viscosity." Should not any Standard for measuring the "kinematic viscosity" be entitled "The measurement of the ratio, coefficient of viscosity/density (kinematic viscosity)"?

Prof. J. M. Burgers and Dr. G. W. Scott Blair in their Report on the principles of rheological nomenclature, presented at the International Conference, Holland, 1948, mentioned that objections have been raised against the use of the term "viscosity" for quantities not having the dimensions of a viscosity. In particular, they had in mind special terms involved by the use of Einstein's equation for suspensions $\eta = \eta_0 (1 + ac)$. Relative viscosity η/η_0 is actually a number; $(\eta - \eta_0)/\eta_0$, usually known as "specific viscosity", could better be called "relative increase of viscosity" while its quotient by the concentration might be called the viscosity factor or the Einstein coefficient instead of "intrinsic viscosity".

(Dr. Treloar has pointed out that if "intrinsic viscosity" be retained it is strongly recommended that c be measured in grams per gram).

Standardising technical committees using these now well-known terms would undoubtedly be glad to hear of acceptable alternative designations devoid of objection.

A Standard of measuring viscosity should not be unreasonably complicated nor the test time too lengthy; it has been found possible with U-tube viscometers to obtain good accuracy with flow times of about 200 sec. when the kinetic energy correction becomes less than 0.1% and may be neglected. In this case only one calibration constant for the instrument is required, an obvious advantage. To avoid inaccuracy in timing with a stop watch, flow times of less than 100 sec. are to be avoided.

It is considered expedient that a viscosity Standard with a known acceptable precision of the order 0.3% repeatability and 0.7% reproducibility should not be sacrificed to the need of quick routine tests of lower accuracy, requiring a second calibration constant of costly determination; if a real need for quick tests is essential for any particular product for internal information, the loss of accuracy could be obtained by the operator by comparison with the standard procedure given.

The second query is whether the use of the quadratic equation, $\text{viscosity} = At - B/t$ is really justified for use with the U-tube viscometer when B is a variable; all that can be said is that with shorter flow times the accuracy suffers to an extent dependent on the kind and size of the instrument and on the variety of the liquid used.

The instability of flow associated with liquids of lower viscosity in standard viscometers and the development of eddies or vortices, etc., are not fully known and the question can well be asked how far the assumption of laminar flow in standard instruments is correct. The flow in an efflux type of viscometer such as a Redwood or Ford cup is

not in accord with Poiseuille's or any other known equation of flow; a curious inverted onion-shaped pattern of flow with "plugs" occurs with liquids of higher viscosity in the cup, and also in the bulbs of U-tube viscometers, while with decrease in viscosity the region of random flow, away from the orifice, increases. Oscillations can sometimes occur at the orifice and adventitious initial movements might set up a circulatory motion (bath-plug effect) which in the extreme, forms an air spiral from top to bottom. Although it is doubtful whether any useful information can be obtained from cup "viscometers" they are favoured in several industries for works control tests where one particular product is under examination.

Several authors are reporting on the development of Taylor vortices and other interesting flow movements in rotary viscometers where laminar flow has been usually assumed. At high shear rates required for the examination of paints, printing inks, and adhesives, fragmentation of the samples can occur. Is this due to "dilatancy" or to the effect of turbulence or to "rheodestruction"? In course of time, no doubt, co-operative testing will establish the accuracy (repeatability and reproducibility) of the newer types of instruments and the extent of the "instrument error" on the rheological results.

In some new high-speed rotary types of instruments the gap between the moving parts of the instrument has been reduced to such small dimensions (to obviate excessive temperature rise in the sample) that the question can well be asked as to whether the results obtained represent those of the bulk material or of its thin films.

E. W. J. MARDLES.

Early bibliography:

J. L. M. Poiseuille: *Memoires*, Acad. Roy. 1842, Translated by W. H. Herschel, *Rheological Memoirs* No. 1, Ed. Bingham, Easton (Pa) 1940.

Horace Lamb: *Hydrodynamics*, Camb. Univ. Press, 1906.

Eugene C. Bingham: *Fluidity and plasticity*, McGraw-Hill, 1922.

Emil Hatschek: *The viscosity of liquids*, Bell, 1928.

Guy Barr: *Monograph of viscometry*. Oxford Univ. Press, 1931.

1st and 2nd Reports on Viscosity and Plasticity. Acad. Sc., Amsterdam, 1935 and 1938.

G. W. Scott Blair: *An Introduction to Industrial Rheology*. Churchill, 1938.

Comments on this article are invited and should be sent to the Editor.

News of Members

From 1st October, 1963, Dr. A. S. Lodge has been appointed Senior Lecturer in Rheology in the Faculty of Technology of the University of Manchester. This is the first university appointment explicitly in rheology in the U.K.

Professor M. Reiner (Haifa) has been awarded the Rothschild Prize which is given each year in Israel for distinguished work in literature or science.

“Rheologica Acta”

Dr. Meskat, a member of the editorial advisory board of this journal, has written to the secretary of the Society proposing a means of closer, international co-operation in rheology. The following is an extract from his letter:—

“As you may take from the number 1, volume 3 of “Rheologica Acta”, we have transformed this publication to an international journal in order to promote co-operation in the field of rheology.

“We intend to make one further step in this direction, also establishing a closer co-operation between the societies and we would suggest to edit ‘Rheologica Acta’ as the organ of the various scientific societies concerned with rheology. This would mean that, for instance, the British Society of Rheology could also publish collectively and free of charge their symposia, the relevant programme of papers as well as the papers read at a symposium. In addition, the members of the British Society of Rheology could buy the “Rheologica Acta” at a price 20% lower. We thus hope that a still increased exchange of ideas between the scientists in the neighbour countries will be possible”.

Dr. Meskat’s suggestion will be on the agenda for the next meeting of the society’s committee.

Future Meetings

At the time of going to press, dates for meetings of the Society after the meeting at Keele in September 1963, are not fixed. A meeting on the rheology of foodstuffs has been proposed and this is likely to be held in co-operation with the Foods Group of the Society of Chemical Industry. At the time of our usual spring meeting however, the Foods Group has a meeting in London so that some modification to our usual programme will probably be necessary. Members are invited to submit papers or suggestions for the particular topic of this meeting to the Secretary.

At the meeting at Keele, it will be proposed that the committee be empowered to set up an exploratory committee to investigate the possibility of forming a centralized organization for research in rheology. Members will be kept informed of developments.

Dr. Stephens of Imperial College is interested in holding a meeting in August 1964 on internal friction in which the Acoustics and Materials and Testing Groups of the Institute of Physics will collaborate with the Society. It has not been decided whether the meeting will take the form of a course or a symposium but in either case suggestions from members will be welcomed.

For the meeting in the Autumn of 1964 present plans are to cover two or three topics *viz.* teaching of rheology, rheogoniometry. A session may be devoted to papers on unclassifiable subjects of general interest

which have never found a place in past meetings. Members are asked to assist their committee with offers of contributions.

The Optical group of the Institute of Physics will hold a conference on "The Physics of Optical Glass" on October 3rd and 4th 1963. Details may be obtained from the Institute at 47, Belgrave Square, S.W.1.

The London meetings of the Joint International Conference on Creep will be held from 30th September to 4th October, 1963 at Church House, Westminster. Enquiries should be addressed to:— The Conference Section, The Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1.

A meeting on Polymer Physics will be held at the Royal Military College of Science, Shrivenham, on the 23rd—25th March, 1964 with a view to forming a Forum for Polymer Physics in Britain. The scientific programme will consist of half day sessions on crystalline morphology, molecular structure, relaxation processes and viscoelasticity, and properties of solution. Organising committee :

G. Allen, Manchester

I. M. Ward, Harrogate

A. Charlesby, Shrivenham

D. H. Whiffen, Teddington

A. Keller, Bristol

Further information from : Dr. I. M. Ward,
Research Department,
I.C.I. Ltd.,
Fibres Division,
HARROGATE,
Yorkshire.

Members may be interested to know that there was insufficient response to justify chartering an aircraft to take members to Rhode Island for the Fourth International Congress. The London travel agents who had provisionally arranged a tour to include participation in the Congress, also failed to attract sufficient support to allow the trip to take place.

Netherlands Rheological Society

The committee of this Society is constituted as follows:—

Chairman: Dr. F. R. Schwarzl (T.N.O. Delft).

Secretary-Treasurer: Dr. C. A. F. Tuijnman (Central Laboratorium Staatsmijnen in Limburg, Geleen).

Ir. C. van der Poel.

Dr. Ir. M. van den Tempel.

The secretariat is established at the Central Laboratory, Staatsmijnen in Limburg, P.O. Box 18, Geleen, Netherlands.

New Members

Elected 11th July, 1963.

NAME AND ADDRESS

G. W. Ridout,
53, Hamilton Avenue, Pyrford, Woking.

M. Braden,
16, Greenway, Harpenden.

P. Lamb,
"Latimer", Blackmore Way,
Wheathampstead.

W. P. J. Baily,
24, Holmwood Avenue, Sanderstead.

A. Kepes,
Société Ethylene Plastique,
Centre des Recherches, Bte. Postale No. 1,
à Mazingarbe (Pas de Calais), France.

T. Diana,
M. Bearzi,
both of S.p.A. Ferrania,
Savona, Italy.

INTERESTS

Suspensions.

Polymers and viscoelasticity.

Polymers.

Synthetic resin latices.

Suspensions and
emulsions.