

BULLETIN



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Hon. Editor:

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FOREWORD

As this will be the last issue before the September Annual General Meeting I would like to remind members that their presence is requested; certainly the last two A.G.M.s have been poorly attended. If you cannot, however, and yet would like to put your ideas forward then the bulletin editor will be pleased to consider them for publication.

Published in a July issue of New Scientist was an article summarising the U.G.C. recommendations concerned with University Spending. With many of our membership and especially members of Council being in academic life obviously the future of the society is in some way linked to that of the academic establishments. It would be of interest to hear if rheological work or departments in which the rheological activity is high have suffered or expect to suffer some cuts.

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FLOW THROUGH POROUS MATERIALS, Part I

by W. M. JONES

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The article is the text of the Presidential lecture given at the September Meeting of the British Society of Rheology, 1979. The lecture was intended as an introduction and was given to a general audience. The intention was to emphasise physical principles. This Part I describes simple models of a porous material and the consequential relevant regimes of flow. Experimental results and some current problems will be given in Part II.

Introduction

A porous material is a solid containing holes which are connected or non-connected, and are dispersed throughout the solid in a regular or a random manner. Examples are soil, rocks, beds of sand, lungs, skin, surface of leaves, brick, clothing, bread, sintered glass or metal powders, brass sheet with the zinc etched out to form porous copper sheet, and so on. Flow situations which are important in those examples are drainage, displacement of oil (and natural gas) from wells, breathing via lungs and through the skin and through the surface of leaves, breathing from the skin through clothing, the washing of clothing, filtration, separation of isotopes by gaseous diffusion, and catalysis. In these examples the relevant fluids could be gases, vapours, or liquids; then there might be mixtures of two or more of these; frequently, the flow is that of immiscible fluids. In soil the granules are themselves porous so that flow can occur between the granules and into the granules simultaneously. In some physical processes the porous material swells as the fluid passes through it so that its properties change with the flow. Even a 'simple' uniform naturally occurring porous material has a complex geometry (i.e. cross sectional shape and lengthwise shape of pores, connected or not) so to appreciate the physical processes which can occur, simple models of the materials and of the flow have to be considered.

Flow Regimes

(i) Viscous (Poiseuille) Flow. In deriving the Poiseuille equation it is assumed the fluid is stationary at the wall of the pipe and the kinetic energy term is neglected. Hence for a pipe of circular cross section

$$Q = \frac{\pi r^4 p}{8\mu} \left(\frac{dp}{dx} \right)$$

where Q is the mass rate of flow, μ is the shear viscosity, and p is the density of the fluid; r is the radius of the pipe and (dp/dx) is the axial pressure gradient at the part being considered. Integration of the

equation over a length l of pipe gives

$$Q = \frac{\pi r^4 p (p_2 - p_1)}{8\mu l} \quad (1)$$

for an incompressible fluid where p_2 and p_1 are the pressures at the two ends of l , whereas for a gas

$$Q = \frac{\pi r^4 \bar{p} M (p_2 - p_1)}{8\mu l R T} \quad (2)$$

where $\bar{p} = (p_1 + p_2)/2$, M is the molar mass of the gas, R the molar gas constant, and T the temperature (Kelvin).

(ii) Slip Flow. As the pressure on a gas diminishes the mean free path λ between molecular collisions increases and the layer of gas nearest the wall is at the average distance λ from the wall. The layer will not be stationary but will move with speed U_w given by

$$U_w = \lambda \frac{dv}{dr}$$

where (dv/dr) is the radial velocity gradient. Substituting this 'slip' velocity U_w into the derivation of the Poiseuille equation gives

$$Q = \frac{\pi r^4 p}{8\mu} \left(1 + \frac{4\lambda}{r} \right) \frac{dp}{dx} \quad (3)$$

Substitution for λ from gas kinetic theory gives after rearranging the equation,

$$Q \left(\frac{T}{M} \right)^{\frac{1}{2}} / \left(\frac{dp}{dx} \right) = \frac{Br^4 \bar{p}}{\mu} \left(\frac{M}{T} \right)^{\frac{1}{2}} + Cr^3 \quad (4)$$

where $B = \pi/8R$ and $C = \pi/2 \left(\frac{\pi}{2R} \right)^{\frac{1}{2}}$. Slip flow will be significant when 4λ is a significant proportion of r .

(iii) Molecular Flow. When $\lambda > 20r$ the rate of flow is controlled by collisions with the wall at which molecules are scattered diffusely. Kinetic theory gives

$$\frac{Q}{M} = \dot{N} = \frac{4}{3} \left(\frac{2\pi}{MRT} \right)^{\frac{1}{2}} r^3 \left(\frac{dp}{dx} \right)$$

where $\dot{N}$ is the number rate of flow of molecules. When different molecular species flow together the lighter molecules pass through more quickly. This is 'separative' flow and is the principle whereby partial separation of isotopes ('enrichment') is achieved by gaseous 'diffusion'.

(iv) Dean Flow in Bent Pipes. When a pipe is bent into an arc of a circle of radius a fluid will tend to move across the pipe away from the centre of curvature, due to inertia. A secondary circular motion will therefore be superimposed on the Poiseuille flow that occurs alone in the straight pipe, and fluid will spiral down the pressure gradient. The dimensionless number characterising the flow

is the Dean number $L = 8(Re)^2 r/a$ where the Reynolds number, $Re = r u \rho / \mu$, in which u is the mean velocity of flow in the pipe. It is usual to express the flow as Q_c/Q_s where Q_c is the rate of flow in the curved pipe and Q_s is the rate of flow that would occur in a similar straight pipe, under the same pressure gradient. When $L < 276$ then $Q_c/Q_s = 1$ but for $L > 276$ the ratio Q_c/Q_s diminishes as L increases.

(v) Flow in an Absorbed Phase. When a molecule impinges on a solid surface it does not immediately bounce back but stays on the surface for a short time. At any instant several molecules will reside on the surface: the adsorbed layer. The binding energy will vary over the surface due to surface structure. An individual molecule whilst having insufficient energy to be desorbed, can have enough energy to move over an energy barrier to a neighbouring site on the surface, thus contributing to surface diffusion. A pressure gradient in the gas phase will yield a concentration gradient in the adsorbed phase so that a net surface diffusion down the concentration gradient ensues. An adsorbed phase can occur at any interface.

Darcy's Law

For a cylindrical sample of porous material of area of cross section A and length l with no radial pressure gradient, the law states

$$V = \frac{Q}{p} = \frac{kA(\bar{p}_2 - \bar{p}_1)}{\mu l} \quad (5)$$

k is the 'permeability' of the material. (The 'darcy' as unit is obtained when A is in cm^2 , l in cm , μ in cP , $\bar{p}$ in atm , and V in cm^3s^{-1}).

Models of Porous Materials

The simplest model for illustrative purposes is a bundle of n straight parallel capillaries each of radius r threading unit area parallel to the (linear) flow. What are the properties of such a model?

Comparing the model with equation (1) then k in equation (5) is given by:

$$k = \frac{n\pi r^4}{8} \quad (6)$$

for an incompressible fluid. The same would be obtained from total gas flow provided $\lambda \ll r$; how much less depends on accuracy. For Darcy's Law to be valid for gas flow within 1% requires $\lambda < 0.0025r$ (see equation 3) and for the flow of air at atmospheric pressure this requires $r > 0.25\text{m}$. Pores through rocks and several other materials are considerably less than this and it is important to appreciate Darcy's law is not applicable.

However, gas flow can be used to characterise porous materials. From equation (4) it is seen that $Q(T/M)^{1/2}/(d\bar{p}/dx)$ varies linearly with $\bar{p}$. Therefore for the capillary model (given r) the intercept i on the ordinate at $\bar{p}=0$ is independent of the gas and of T and the

slope s of the line varies as $(M/T)^{1/2}/\mu$. These are found to be so in practice. Hence (see equation 4)

$$r = \left(\frac{s}{i} \right) \left(\frac{C}{B} \right) \mu \left(\frac{T}{M} \right)^{\frac{1}{2}}.$$

The value of r obtained in this way is 'the mean pore radius'. Flow of a gas is a convenient means of characterising material such as cardboard; the flow of a liquid would be slow and would yield no information concerning pore size. Permeability is obtained from gas flow even when $\lambda \ll r$, using

$$k = \frac{s\mu}{A} R \left(\frac{M}{T} \right)^{\frac{1}{2}}.$$

Figure 1 illustrates displacement of one fluid by another in the capillary model. In 1(a) a non-wetting fluid (say air) is displacing a wetting fluid. For air to bubble through the capillaries requires a minimum pressure $p = 2\omega/r$ where ω is the surface tension of the fluid. ω and p being known enables r to be evaluated. In this circumstance r is the "hydraulic radius". Alternatively a non-wetting fluid (usually mercury) (Fig. 1(b)) can be forced into the empty capillaries. For any to enter requires a minimum pressure $p = 2\omega/r$ and r can be evaluated. The rate of flow through the model is given in 1(c). In practice with real porous materials, the lowest pressure at which flow starts yields a value for the largest pore and the largest pressure at which additional flow occurs yields a value for the smallest capillary. The shape of the intervening curve can be analysed so as to give a distribution of pore sizes. (The total amount of fluid entering yields a value for t).

A drop of wetting fluid trapped in a capillary (1(d)) can sustain a high pressure difference without moving. For example, for water in a pore of $1\mu\text{m}$ radius, the pressure drop supportable is 1.5 atm and the pore would be effectively sealed off to flow of another fluid. The pressure required to move the drop would probably approach 3 atm. Such effects are very important in the displacement of oil by water, from rocks. To offset the effect surfactants might be used to reduce the interfacial tension.

Kozeny used the capillary model to derive an equation for flow in terms of porosity and surface area. The total volume of pore space is $n\pi r^2 Al$ in an external volume Al and therefore the fractional void volume or "porosity"

$$t = n\pi r^2 \quad (7)$$

Similarly the total surface area of capillary is $2n\pi r Al$ and so the "specific surface area"

$$S = 2n\pi r \quad (8)$$

Hence from (7) and (8)

$$r = 2t/S \quad (9)$$

and from (7) and (9)

$$k = \frac{n\pi r^4}{8} = \frac{t^3}{2S^2} \quad (10)$$

Substitution in equation (5) gives

$$V = \frac{Q}{p} = \frac{t^3 A (p^2 - p^1)}{2S^2 \mu l} \quad (11)$$

Flow in real material is found to vary as t^3 and S^2 as predicted by (11). Arnell made analogous modifications to the slip flow term. The resulting equation (with modified numerical coefficients) is the Kozeny-Arnell equation.

Packed-sphere Model

Consider a simple-cubic arrangement of identical spheres of diameter D . The number per unit volume is $1/D^3$ and therefore the fractional occupied volume

$$(1-t) = \frac{1}{D^3} \left(\frac{\pi D^3}{6} \right) = \frac{\pi}{6} \quad (12)$$

and the specific surface area

$$S = \frac{1}{D^3} (\pi D^2) = \frac{\pi}{D} \quad (13)$$

Substitution into equations (9) and (10) gives

$$r = \frac{2t}{S} \approx 0.3D \quad (14)$$

$$\text{and } k \approx 0.006D^2$$

These equations show that porosity is **independent of the size of the grains** which make up a porous material, whereas the permeability **diminishes as the grain size diminishes** (varying as the size squared). The pore radius diminishes as grain size diminishes. The actual values depend on the packing. For close packing the porosity is at a minimum of 0.26. However, when there is a distribution of grain sizes small grains can occupy the spaces between the largest and so reducing the porosity below 0.2. It is pertinent to point out that the hydraulic radius (= 2 x area/circumference) of the space between four spheres in contact in a square arrangement is 0.14D which is just half the mean pore size as given by equation (14).

When granular beds are made up artificially by packing particles into a container, special filling techniques are used (e.g. pouring the granules past sets of cross wires arranged at 45° to each other) and vibrating the container as the grains fall into it. When the container is full and firmly closed with a suitable lid the packing then remains constant independently of the flow rate of fluid through the bed and of mechanical vibration. Such a bed is a 'consolidated' bed and the value of its porosity t , lies in the range 0.35 to 0.4, mid-way between that for close packing of spheres and that for simple packing of spheres.

More Realistic Models

The first simple modification of the capillary model is to say that obviously the pores are not straight. If l_e is the length of the average pore through a length l of porous material then l_e/l is the 'tortuosity factor'. When the tortuosity is attributed to the length of path around a sphere compared with the diameter of the sphere, then the tortuosity factor is $\pi/2$. Most workers use that value although a factor $\sqrt{2}$ is sometimes used.

Different cross-sectional shapes of pores have been considered. When these are not circular it is important to realise that secondary circulating flows occur in the corners at right angles to the axial flow. Various distributions of pore sizes (or their lengths and of their radii) arranged in series and in parallel, with varying degrees of connectivity, constitutes the most general model (but still restricted to cylindrical pores). The variables in the model are adjusted to reproduce the measured flow of adsorbable gases, using computer simulation. An example of such work is the series of papers by Nicholson and Petropoulos (Part I (1968) to Part VII (1977)).

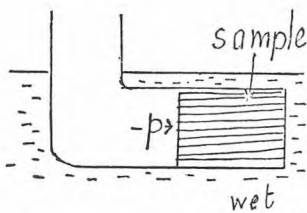
In circumstances where extensional flow is important (e.g. flow of dilute polymer solutions) the convergence of pores is relevant, such as that occurring at the approach to the constriction between touching spheres, see, for example, James and McLaren's (1975) treatment of the problem.

References

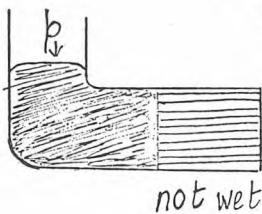
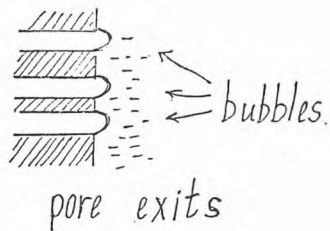
- James D F and McLaren D R 1975 J Fluid Mech 70 337-46
Nicholson D and Petropoulos J H 1968 J Phys D 1 1379-85
1977 J Phys D 10 2423-28

A Bibliography will be given at the end of Part II

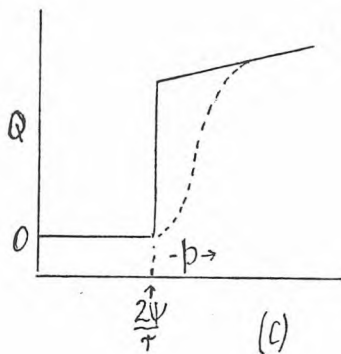
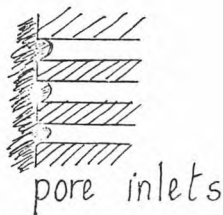
FIGURE 1



(a)



(b)



(c)



drop trapped



(d)

$$\Delta p = \frac{4\psi}{r}$$

CONFERENCE REPORT

RHEOLOGY OF RUBBERY MATERIALS AND RUBBER COMPOUNDS

BSR-BGR Joint Meeting — April 7th - 9th, 1981 — Liège, Belgium

The joint meeting organised by the British Society of Rheology and the Belgian Group of Rheology attracted about 40 participants from seven countries. The practical implications of the subject "Rheology of Rubbery Materials and Rubber Compounds" were obviously an important aspect of the Conference, as 2/3 of the participants came from industry. The Town and the University of Liège provided warm hospitality and clement weather allowed all the participants to appreciate the beautiful environment of the Sart-Tilman Campus.

The difficulties of the subject were stressed in the official welcoming address. "Twenty years ago", Vice-Rector Dehousse said, "I discovered the difficulties of using rubber for civil engineering purposes . . . a mysterious material . . . in the Aztec language, the word "kahuchuc" meant "weeping wood". Since its discovery, this material has not stopped weeping nor causing rubber processors to mourn . . .".

Rubber technology, whilst being one of the oldest which have shaped our modern world, still remains more an art than a science, as most of its techniques were developed by trial-and-error methods. Only recently has the experimental and theoretical progress made in the understanding of the flow behaviour of pure polymers, particularly thermoplastics, been applied to the rheology of rubber processing.

K. N. G. Fuller and A. G. Thomas reported an investigation on the creep and recovery behaviour of uncrosslinked, unfilled natural and synthetic polyisoprene rubbers. From their observations, they developed a model based on Lodge's network theory in which the stress is supported by network structures assumed to be continually breaking and reforming. P. R. Freakley and K. B. Basir used a TMS rheometer to investigate the influence of batch internal mixer variables on the characteristics of carbon-black-filled butyl rubber compounds. They observed that over the practical range of mixing conditions, the variations in viscous flow properties were negligible but both stress relaxation and wall slip characteristics changed significantly.

A series of three companion papers were presented by J. R. A. Pearson, S. M. Richardson and A. M. Hull on models for flow of highly elastic fluids through slits and nozzles. The starting point of their theory is the postulate that through a converging channel, a self-lubricating layer and a core arise and that the fluid is in two quite different states on either side of the interface separating the two regions. It follows that a simple shear viscosity will be relevant in the

lubricating layer and an extensional viscosity in the core region. Experimental results on filled rubber compounds were shown to justify this approach.

G. M. Bristow reported effects of variation in natural rubber source and in the masterbatch mix cycle on processability of the stocks expressed either as Mooney viscosity or the flow behaviour observed in capillary rheometer tests.

J. L. Leblanc discussed the main factors affecting post-extrusion swelling and critical conditions for the onset of extrudate distortion of rubber compounds, i.e. the nature and molecular characteristics of the elastomer, the grade and level of filler, the cumulative energy introduced into the rubber during the mixing operation, the mixing procedure and the temperature and shear conditions of the extrusion process. Experimental results on industrial compounds were presented and discussed.

N. Probst and J. Iker showed how statistical data treatment allows carbon black producers to establish models predicting the influence of carbon black type and level on viscosity and extrusion shrinkage of SBR compounds, using carbon black characteristics and empirical correlation factors.

B. J. R. Scholtens and H. C. Booij described an extrapolation method to estimate the equilibrium modulus of EPDM networks. This method, based on the linear theory of viscoelasticity, consists of obtaining the relaxation spectrum by an iterative procedure then recalculating the storage and loss moduli.

B. Duperray reported dynamic properties of carbon black filled natural rubber and SBR compounds, as determined using a viscoelasticimeter. He showed that, when using the time-temperature superposition principle, the shifts factors as determined from the storage and loss moduli are different. To explain this phenomenon, it was argued that a distribution of activation energies is superimposed on to the classical distribution of relaxation times.

C. Creasy, A. Chakrabarti and T. E. R. Jones reported torsional vibrational properties of rubber cylinders (natural and nitrile rubber compounds), as determined through an adaptation of the Weissenberg Rheogoniometer.

A new instrument to assess the dynamic properties of rubber compounds was described by C. De Meersman. A small indenter is forced a constant depth into the rubber specimen and the relaxation of the indentation force is measured. Using a generalized Maxwell model to simulate rubber behaviour, the dynamic behaviour of the tested material is then derived from the relaxation measurement.

Finally, J. R. A. Pearson gave a much appreciated performance in summarizing the contributions of G. V. Vinogradov and Yu. G. Yanovsky who were not in a position to attend the meeting. He out-

lined the main points of their theory of the high elastic state, and mentioned recent results on blends of HMW rubbers, LMW rubbers, and solvents.

This straight description of the contributions presented does not take into account the many open discussions which were frequently lively and controversial. One of the most important difficulties of the field concerned appeared in the earlier discussions, i.e. the fact that rheologists and rubber technologists were often using completely different approaches and languages. Whilst it is recognized that the empirical approach of the rubber industry has been successful — are we not driving on excellent tyres these days? — the necessity for a better understanding of rubber processing is becoming clear and urgent. The times of cheap energy are over; the amount of scrap and rejects from rubber processing not only dictates the profit but also, more frequently today, is a matter of life-and-death for many companies. These are the reasons for the recent interest of the rubber industry in the rheology of processing, as the possible way towards more efficient operations.

One cannot forget in this report of the meeting the warm hospitality of the Town Authorities, with the welcome party in the XVIIth century City Hall and the Conference Dinner, top event as promised by the Belgian Committee. In a lovely historic building fronting on to the Meuse River, the participants appreciated the cooking art of Liège's chefs and the fine taste of French wines. That is also an interesting aspect of the necessary collaboration between the European Societies of Rheology.

JEAN L. LEBLANC
President of the BGR

MEMBERSHIP NEWS

The following applications were approved by Council at its last meeting:

Mrs. Eve Jenkins
B.Sc. (Hons.)
peta, CDI

Dr. James Speakman
Ph.D., C.Chem., MRIC
pea, FGHO

Dr. Geoffrey John Brownsey
B.Sc., Ph.D.
fetsa, EFGLM

Dr. Francis Sidney Baker
B.Sc. (Special), Ph.D.
fetsa, CDEO

John Eric Daborn
B.Sc., MIMC
pea, J

Ramesh Pisipati
MS
fetsa, BD

Prof. J. J. Ulbrecht

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New York 14260, U.S.A.

Resignation (June 1981)

J. A. Spence, Queen's College, Dundee.

Mailing of Bulletin and Rheology Abstracts

During the past year, the computer that handles the Society's mailing list underwent some refurbishing and as a consequence there was some problem over the despatch of Bulletins and Rheology Abstracts to certain members.

If you are one of those affected, please let the Membership Secretary know and he will get missing copies of the journals sent to you.

Literature Available

R. J. Cole has a set of Rheology Abstracts 1958 - 1975 (excluding 4 (1961) No. 4) which he will donate to a worthy (non-commercial) recipient who is prepared to pay the cost of transport/postage. Contact the Secretary.

The Secretary has copies of Rheology Abstracts available on the same basis which came to him from former Membership Secretary R. R. Addis. There are two incomplete sets 1958 - 1969 (both missing 7 (1964) No. 4, 10 (1967) No. 4 and 12 (1969) No. 4; the second set also lacks all of volume 6 (1963)). In addition there are a few extra numbers [4 (1), 5 (1), 13 (2), 13 (4), 14 (1), 14 (3), 16 (2), 17 (1), 17 (3), 19 (2)] and the complete 1976 volume, 19 (1 - 4). Prior to 1958 abstracts appeared in the Bulletin, and there are three complete

sets of Bulletins from December 1948 (No. 21) to December 1957 (No. 53). There are also single copies of Bulletins (13, 14, 15, 18, 20, 24, 27, 32).

The Secretary and Bulletin Editor receive, and will lend, copies of *Dokumentation Rheologie* (of which No. 46 (1980) has just arrived) and *Nihon Reorogi Gakkaishi* — the journal of the Society of Rheology, Japan (which is in Japanese apart from abstracts which appear in *Rheology Abstracts*).

Change of Employment

Dr. Raj Khanna, a BSR member since 1966, has left Berger and is now working as a consultant to the United Nations Industrial Development Organization and as a private consultant. His consulting services are offered in the fields of surface coating, PVC technology and process control viscometry.

His new address is 28 High Road, Waterford, Herts. SG14 2PR. Telephone Hertford 59903.

Death of former Bingham Medalist

Dr. Johannes Martinus Burgers, 86, a leading authority on fluid dynamics and professor emeritus of the University of Maryland's Institute for Physical Science and Technology, died of pneumonia Sunday at the Sligo Gardens Nursing Home in Takoma Park. He had Parkinson's disease.

Born in Arnhem, The Netherlands, Dr. Burgers studied advanced mathematics and theoretical physics before entering the University of Leiden, where he studied with the world-renowned Dutch physicists H. A. Lorentz and Heike Kamerlingh Onnes, earning a doctorate in mathematics and physics in 1918.

In the 1940s, he was a founder of the International Union of Theoretical and Applied Mechanics, which was admitted to the International Council of Scientific Unions in 1947. He served as general secretary of the union from 1946 to 1952, was a member of its general assembly and served as secretary of its Joint Commission on Viscosity and Plasticity.

He also helped in organizing the first three International Symposia on Cosmical Gasdynamics and two international congresses on rheology.

Dr. Burgers was a member of many professional and academic societies, including the Royal Netherlands Academy of Sciences. He was a fellow of the American Institute of Aeronautics and Astronautics, the New York Academy of Sciences and the Royal Aeronautical Society in Great Britain.

His awards included the 1960 prize of the Italian Academy of Science at Turin and the Bingham Medal of the Society of Rheology (1964).

PERSONAL NOTE

T. A. Strivens

Born in 1934. Educated at Plymouth College and Taunton School. Read Botany and Chemistry at the University of Wales (Cardiff) and graduated in 1955 with a Bachelor of Science Degree.

Employed by W. G. Pye and Co. (Cambridge) doing research into electrochemical methods of chemical analysis. Joined I.C.I. (Paints Division) Research Department at Slough in 1963 to do fundamental research into the electrodeposition of paint. Since 1970, has been doing research into the mechanical properties of paint films and all aspects of the rheology of paint and paint components. Current

research interests are in the rheology of concentrated polymer solutions and concentrated suspension and dispersion systems. Promoted to Group Leader (Physics) in 1979.

Elected to Council of British Society of Rheology 1980. Member of the (American) Society of Rheology.

Interested in classical archaeology, music and literature. Active squash player.

LETTER TO THE EDITOR

Department of Building Engineering
Muspratt Laboratory
University of Liverpool
21st January, 1981

Dr. C. R. Dimond
Morgan Thermic Ltd.
Technological Centre
Bewdley Road
Stourport on Severn
Hereford/Worcestershire.

Dear Editor,

I am writing to take up the point made in the report on the 8th International Congress (Bulletin No. 4, 1980) about the organisation of major congresses. I can appreciate the problems of mental and physical agility required to attend lectures in six parallel sessions but I recently experienced the opposite kind of frustration. The 7th International Congress on Chemistry of Cement in Paris, June 1980, was organised into seven themes, each of which was allocated half a day. In this time, a chairman tried to summarise the papers presented in his theme (an average of 40) in addition to asking three or more principal reporters to mention their reports. There was then a break for a one hour poster session, followed by questions, which were not directed to the authors but to a panel of experts. The congress participants as a whole never saw any of the authors and personally I found the poster sessions to be the most valuable part of the formal proceedings.

I think that the parallel session approach, however exhausting, is much to be preferred to this 'theme' approach where no one has enough time to say anything useful.

Yours sincerely,
P. F. G. BANFILL

NEW BOOKS

FLOW PROPERTIES OF POLYMER MELTS 2nd edition

by J. A. Brydson

This is a new, revised and updated edition of a familiar work in which the author deals with the basic features of simple one-dimensional rheology of plastic melts, covering flow properties and fluid mechanics of non-Newtonian fluids for representative melts. Its modest level of mathematics makes this lucid and concise text an ideal introduction to flow properties for all concerned with the design of processing equipment, with economic manufacture and with quality control.

Contents: Flow properties, an introduction; Flow through channels of simple cross-section; Measurement of shear flow properties; Factors affecting viscous shear flow; Elastic effects in polymer melt flow; Elongational flow; Application of rheological studies to polymer processing; More complex rheological problems; Appendix: Derivation of flow equations.

246pp Figs. Hardback ISBN 0 7114 5681 X 1981 £22.00

POLYMER MELT RHEOLOGY A Guide for Industrial Practice

by F. N. Cogswell

From a basis of industrial research, the author investigates the ways in which melt flow behaviour can be exploited by the plastics engineer and technician for better efficiency of processing operation, control of end-product properties and selection/development of polymers for specific purposes. This clear, thought-provoking and, above all, practical guide to problem identification and solution includes engineering strategies and data intended for immediate application in industry.

Contents: Introduction; Fundamental concepts; Rheometry for polymer melts; Physical features and flow; Rheology and structure; Adventitious flow phenomena; Rheology in polymer processing; Future developments in polymer rheology; Appendices.

192pp Figs. Hardback ISBN 0 7114 5608 9 1981 £18.00

Both books being published by George Godwin Limited, 1-3 Pemberton Row, Fleet Street, London EC4P 4HL, in association with The Plastics and Rubber Institute.

FUTURE CONFERENCES

THE INSTITUTE OF MATHEMATICS AND ITS APPLICATIONS

Conference on FLOWS IN POROUS MEDIA

University of Nottingham — September 14th - 16th, 1981

The IMA jointly with the Institution of Chemical Engineers is holding a conference on Flows in Porous Media at the University of Nottingham from September 14th - 16th, 1981.

The theory of flow in porous media is very diverse in its subject areas and includes such topics as multiphase gas flow through chemically active materials, oil recovery principles, water flow through soils, rain percolation through snow and many more areas which use the theory both directly and indirectly. Equally diverse are the disciplines of practitioners of the theory which range from chemical, petroleum, mining and civil engineers, hydrologists and geologists to applied mathematicians. Because the detailed description of a fluid flow in a porous medium is highly complicated, even assuming it is possible geometrically to describe the medium itself, the search for understanding usually evolves into producing a "mathematical model". These models are of varying complexity depending upon the underlying physical problem and consequently require a variety of solution techniques, both analytical and numerical.

An aim of the meeting is to give "state of the art" reviews in the principles of fluid flow in porous media and to describe a wide range of applications.

Speakers will include: Dr. S. Hibberd, AFIMA, and Dr. J. T. Holden (University of Nottingham), Dr. K. Walton (University of Bath), Dr. D. S. Riley, GradIMA (University of Southampton), Dr. I. M. Cheshire (AERE, Harwell), Dr. A. B. Tayler, FIMA (University of Oxford), Dr. J. van Brakel (Technische Hogeschool Delft), Dr. R. S. Peckover, AFIMA, and Dr. B. Turland (Culham Laboratory, Oxford), Professor M. Cross (University of California). Time will be given for discussion periods and poster sessions.

The conference will begin on the afternoon of Monday, September 14th, and will end on the afternoon of September 16th. Residential accommodation will be available.

RHEOLOGY IN FRANCE

The sixteenth annual conference of G.F.R., to be held in Paris on 9th and 10th December, 1981, has as its theme the applications of rheology to industrial fabrication. The programme will include the following papers, all presented in French.

- Z. Sobotka: recent progress in the theory of plastic flow.
- G. Regazzoni and F. Montheillet: the effect of memory in the heat behaviour of aluminium deformed in torsion at variable speed.
- A. Faessel, B. Migaud and M. de Vathaire: the calculation of forces and couples in rolling.
- P. Frou: the optimisation of rolling simulated using plasticene.
- C. Homer: the superplasticity of brass at high deformation rates.
- P. Lipinski and G. Pluvinage: relation between the law of behaviour and measured strength under dynamic conditions.
- J. D. Weber: the swelling of 'brames' in the continuous casting of steel.
- R. Lapasin and A. Papo: time dependency of gypsum plasters.
- J. P. Doucet: the control, registration and regulation of viscosity with the aid of the *sofraser* industrial collector.
- J. P. Ibar rheo-milling, a new procedure for controlling the physical properties of plastic materials.
- J. M. Aribert and A. Doustens: the characterisation of slow Bingham flows in several geometries, with applications to isotropic filtration.
- P. Montmitonnet and F. de la Mare: determination of plastic and viscoelastic properties of metallic soaps by measuring their resistance to heat.
- Y. deMay and J. F. Agassant: the application of linear stability and bifurcation theory to the study of isothermal and non-isothermal textile spinning.
- G. Elbez: some hydrodynamic properties of wood glues.
- S. Dayan, J. M. Gilli and P. Sixou: the rheology of spinning solutions of mesomorphic polymers.
- M. Frias and R. Marrao: Vulcanisation and rheological control.
- J. Briant, D. H. Fruman and D. Quemada: the transport of heavy crude oil in an oil-water emulsion.

For further information contact: M. E. Absi, CEBTP, 12 rue Brancion, 75737 Paris, Cedex 15, France.

The German society of Rheology and the Austrian Group of Rheologists have taken over the tasks for the preparation and performance of a first

"Meeting of European Rheologists"

14th - 16th April, 1982, at Graz/Austria

All European societies and groups of rheology are cordially invited to join us and make it a European Meeting in fact. Austria as a neutral country is easier to visit for East European rheologists and therefore a particularly suited country for the first European Meeting. For promotion of this European meeting the German and Austrian Societies will not arrange any other rheological meeting in their countries in 1982. The scientific part of the European meeting could consist of some review papers (30 - 40 min) and numerous contributed papers (15 - 20 min). Enough time should be available for discussion and for exchange of views and experience. The official conference language is English but the local language (in that case German) is admitted too in a limited scope, for example within one session, if there are several sessions. With this we follow a proposal of Dr. Huet (France).

The meeting aims to cover the following areas

- Viscoelastic behaviour of organic solids (plastic, rubber, etc.)
- Rheology of melts and solutions
- Biorheology and medical applications of rheology

An attractive social programme for all participants and a special ladies' programme are planned.

RESEARCH VACANCY

UNIVERSITY COLLEGE OF SWANSEA

Senior Research Assistant

Applications are invited for the vacancy of Senior Research Assistant in the Department of Computer Science, to work on an S.R.C. project on the numerical simulation of time-dependent flows of non-Newtonian liquids. Applications should preferably have a Ph.D. in an area of numerical mathematics and an interest in numerical fluid dynamics.

The appointment, will be for two years, renewable on an annual basis, from 1st October, 1981, or as soon as possible thereafter. The commencing salary will be up to £6,880 per annum.

Further particulars and application forms (two copies) may be obtained from the Personnel Office, University College of Swansea, Singleton Park, Swansea, SA2 8PP, to which office they should be returned by *Friday, 18th September, 1981.*

DIARY

1981

September 8 - 11. Newcastle. Stretching Flows and General Rheology (British and Italian Societies of Rheology).
B.S.R. A.G.M. to be held during this meeting.

September 30 - October 2. 2nd European Conference on Clinical Haemorheology — London.

October 11 - 15. 53rd Annual Meeting of the Society of Rheology — Louisville, Kentucky.

December 9 - 10. 16th Annual Conference of G.F.R.

1982

March 29 - April 1. Cambridge. Deformation, Yield and Fracture of Polymers (Plastics and Rubber Institute with the British Society of Rheology and other societies).

April 14 - 16. Graz. See Bulletin article.

September 21 - 24. Rheology and Microstructure. Trinity Hall, Cambridge.