

Statistics on BSR.

Hadley on A G's meeting.

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RHEOLOGY AND TEXTURE OF FOODSTUFFS

**Joint Symposium of the Food Group of the Society of Chemical
Industry and the British Society of Rheology
London University School of Pharmacy, 1967**

The two-day symposium was attended by about 190 delegates from 9 different countries and 18 papers were presented. From the organisational point of view the meeting was one of the best I have attended. The size was right, there were pre-prints, introductory and concluding talks were to the point, the slides were clear and right way up first time, chairmanship was decisive, the speakers were audible, the food was good and clean and whenever I wanted to sit there was a seat available. Much of this was due to Mr. Sherman and if he manages to publish the monograph in reasonable time I shall give him 99 marks out of 100. I withhold one mark because he did not automatically reject all papers without an abstract.

A symposium under the title of "Texture in Foods" was held by the S.C.I. Food Group in 1958 (S.C.I. Monograph No. 7). Comparing the records of the two symposia, it appears that progress during the last 8 years has been slow but steady. If there were "flashes of light" I missed them. However, it seems that where there were areas of confusion there are now more defined areas of ignorance. This is progress.

It seems to be accepted that Rheology is the science of the deformation of matter. As a science, Rheology might be expected to have evolved from the sensory via the empirical to the fundamental stage. Unfortunately, as Professor Ward pointed out in his closing address, foods are generally so complex that empirical performance may be the only possible evaluation. Nevertheless, there was a definite move towards c.g.s. measurement although no tensor concepts were used at any time. Rheological models (springs and dash pots) were often quoted. Although fictitious these models are intellectual jigs or what an engineer might call high tolerance concepts. In that way, they are very useful in classifying real rheological food properties. Some authors suggested that a certain spring or dash pot was equivalent to a structural component in the material; I am inclined to disagree.

There is no accepted definition of texture. Perhaps it is the structure of food as perceived unaided. There is a dilemma here; while the sensory test is the most primitive approach in rheology, it is the ultimate criterion in texture testing from the consumer's viewpoint. However, with some good will it is possible to divide the papers into rheological and textural studies.

Texture

Dr. Harper drew attention to the necessity of sensory evaluation of texture and consistency whenever the consumer is involved. He reviewed some of the descriptive terminology and discussed some of the basic problems and methods involved in quantitative sensory evaluation. Selected aspects of the forces and mechanisms involved in the perception of texture and consistency were considered. Various examples of sensory-instrumental correlation were discussed, with special emphasis upon instances in which only a multi-dimensional approach could do justice to the facts. The possibility of regarding certain examples of the perception of texture and consistency as pattern perception was explored. Finally, reference was made to the continuing lack of permanent facilities for comprehensive multidisciplinary studies, a state of affairs which was deprecated and needs to be rectified.

Dr. Drake stressed that a number of different processes are involved in the biorheology of mastication. He outlined the anatomical features of the muscles, jaws and teeth and their neural connections with the brain. He also discussed the forces and mechanisms involved and reviewed some of the experimental studies which have been made. He described some of the instrumental tests which have been developed and which simulate the process of mastication. (At the last symposium only maximum biting loads were available. Now mean biting stresses are known, thanks to volunteers who walked about with gauges in their teeth and wires in their mouths.)

Dr. Wood compared the apparent viscosity of soups with the psycho-physical response of tasting panels. The perception of consistency was related to the physical stimulus by a power law.

Three structurally very complex materials, biscuits, fish and meat were dealt with by Drs. Wade, Love and Lawrie respectively. Dr. Wade described a biscuit texture meter, a small disc saw which cuts a stack of biscuits. The time taken, to make a standard saw cut correlated well with panel assessment. Dr. Love considered the relation between histology and texture of fish muscle. His work was based on a method he had described at the previous symposium in 1958 and which consisted in dispersing fish muscle by homogenisation. The microscopic appearance of the homogenate reflected toughness and softness of fish. Toughness, he said, was related to increased cohesiveness of the myofibrils, while softness appeared to result when structural material was removed from them.

Dr. Lawrie dealt with factors modifying meat tenderness. From these last three papers it appears that with the structural complexity of biscuits, meat and fish basic rheological methods have at present reached the limit of their usefulness. It seems that the best we can hope for is to use *any* test, physical or chemical and correlate it statistically with consumer response.

Rheology

The rheological papers covered the whole range of materials with the accent on visco-elastics.

Dr. Autard, speaking on the consistency of cake batters seemed to regard them as Newtonian liquids. Dr. Prentice, dealing with cream (a 50% fat in water emulsion), described its rheologically remarkably stable structure and showed by means of a concentric viscometer which could also be used with oscillations, that under low rate of shear cream could be regarded as a Non-newtonian elastic liquid.

Plastic materials were represented by Dr. de Man's paper on the effect of mechanical treatment of the rheology of butter. He assumed fats to be a 3-dimensional crystal network held together by van der Waals forces. Butter work-softened when forced through perforated plates and he reported his studies with a cone penetrometer on hardness and the shear press on extrusion pressure and work of extrusion.

All remaining papers dealt with visco-elastic foods but the authors' viewpoints were very different.

The papers of Drs. Shama and Mohsenin dealt principally with visco-elastic measurement. Dr. Jones spoke about empirical tests on Agar Jelly, Professor Ward on the behaviour of dilute gelatin gels at large strains. He showed that the breaking extension and so the breaking load increased with molecular weight.

The largest group of papers (Drs. Bloksma, Heaps and Muller) dealt with dough rheology, mainly from the chemo-rheological point of view. Although specifically useful, in the wider sense the papers were a little disappointing. Most of the basic problems still remain.

In a useful summary Professor Ward compared the meeting of 1958 with the present one. His two main points were that too little progress had been made in the field of mastication analysis, perhaps due to lack of funds. Secondly, he pointed out that in rheological performance testing empirical measurements were permissible. If there was no such performance test, measurements should be in the c.g.s. system. He asked authors to publish sufficient data to allow evaluation of their hypotheses by independent workers.

To summarise, the meeting was useful, if unspectacular. The fields of rheology and texture of food are de-limiting, the former becoming less empirical, the latter more statistical which is as it should be. Great stumbling blocks are the enormous structural complexity of food and its twin aspects of rheology and texture. It is impossible to say, if, when and where a systematic breakthrough will occur or to quote "the Bard":

"If you can look into the seeds of time,
And say which grain will grow and which will not,
Speak then to me."

There were many seeds to be found at the Symposium but as yet, no dazzling bloom.

H. G. MULLER.

MEMBERSHIP SURVEY, 1966

D. C-H. CHENG AND D. W. HADLEY

Summary

The 1966 list of members is used as the basis for a statistical study of membership interests and employment. For members resident in the United Kingdom the results are compared with those of the N.E.L. survey of Rheological Research in Britain, and with Board of Trade figures.

Types of rheological work under-represented in B.S.R. are enumerated, and suggestions are made for possible improvements in the classification of members' interests. The relation of the result to other affairs of the Society is also discussed.

Introduction

The membership list gives, in principle, the interests, place of employment and status of all members of the Society. It was thought a useful exercise to use the list published in March 1966 to determine the proportion of members interested in different aspects of rheology, and to examine the division of employment between industry, government directed establishments and research associations, and universities. Comparison with membership lists dated March 1963 and October 1959 can give a picture of the growth of the Society, and show whether the increase in membership is uniform or concentrated in certain sectors.

Certain advance pre-publication information was available from the N.E.L. Report, "Rheological Research In Britain, 1966." Although these data listed organisations rather than individuals, and used a classification scheme sub-divided in terms of materials and phenomena studied, the information could be transformed to enable a direct comparison to be made with B.S.R. membership, and hence show how the Society is represented in different fields.

A comparison with Board of Trade figures for labour employed, production and various expenditures of different industries in which rheology plays a part is also made. Allowing for the relative importance of rheology in these industries, this would also show how the Society is represented in different industrial fields.

It should be emphasised that the survey was not commissioned by the Council of the Society, and any opinions expressed are those of the authors as individuals.

Accuracy of Basic Information of Membership

The membership list of 1966 is not complete, and there are discrepancies with earlier lists. Where details of interests, place of employment and status have been omitted, an attempt has been made to obtain the information from works of reference, lists of attendance at

conferences, and personal knowledge. Undoubtedly some errors and omissions have been made, but the inaccuracy is not thought large enough to upset the overall balance of data.

At present members elected before 1st July in any year are recorded as having joined the Society in the previous year. This procedure, applied consistently, appears to be of no more than five years' duration, and is partly responsible for the irregularities between different membership lists. A further cause of error is the significant number of omissions from the earlier lists.

Where sub-classes of membership have been made the division is necessarily somewhat arbitrary and irregularly defined—particularly in regard to status. A further difficulty concerns research institutes associated with a university; in these establishments only a proportion of the staff has academic status. However, no deliberate bias was applied during the sub-division processes, and errors are liable to be randomly distributed.

The published list has been updated to record all members elected during 1966, but no deletions have been made for resignations during that year. Scientists are a much travelled community, with the result that several members who joined the Society in Britain are now resident overseas. Such travellers are represented in the analysis according to their address in the relevant membership list.

Results and Discussion

(a) Total Membership

The numbers of members resident in Britain, Australia and elsewhere overseas in 1959, 1963 and 1966 are shown in Table 1. In the two latter years further subdivision has been attempted into: (i) universities and other educational establishments; (ii) research associations and government directed laboratories; (iii) industry. Totals in the final column of Table 1 are slightly higher than the sum of the three preceding columns, because the occupations of all members are not known.

The figures show that the total membership of the Society is still growing relatively rapidly, but suggest that the number of university members is increasing at a faster rate than the number in industry. Confirmation of this trend is shown in Table 2, which gives a breakdown of members elected 1964–66. Members whose occupations are completely unknown have been omitted from this Table, but even so the numbers for Australia cannot be considered reliable.

There are at least three reasons which can account for this shift in emphasis in members' occupations; two of these reasons are obvious, and inter-connected; the third is less obvious. British Universities have been passing through a period of rapid growth, with the greatest increase in staff occurring in the less traditional fields. A substantial number of these new academics are involved in projects subsumed under the general title of rheology, and so have provided a fertile

recruiting ground for the Society. In addition several existing members have transferred allegiance from industry to university (Editors of both the Society's regular publications are included in this category) thereby accentuating the general trend. Finally, and as an example to all members, it should be noted that the respective efforts of Dr. K. Walters and Mr. B. Warburton, have led to there now being seven representatives of the Society at University College, Aberystwyth, and nine at London University School of Pharmacy.

Table 3 shows a not-completely-successful attempt at determining what proportion of the present membership was elected in which year, and also lists comparisons with earlier records, so that the relative permanency of interest of members elected in any year could be determined. Omissions in earlier lists, and differences in defining the start of the Society's year are both important sources of inaccuracy. One suspects serious omissions must account for the 1959 list showing only 4 members elected during 1955, whilst the 1966 list shows 15 existing members as having joined during that year.

The data indicate, however, that the number of new members varied significantly from year to year. Personal experience suggests that the variation depends on the number of non-members attending a B.S.R. conference, and on the capacity of certain existing members for persuading these visitors to join the Society.

A further indication is that a large number of members elected between 1957 and 1962 were not interested in the Society, and soon resigned from it. Overseas members show less tendency to resign, presumably because they do not have to be persuaded to join, and because they have less opportunity for borrowing another member's Rheology Abstracts.

(b) Group Interests

New members are asked to state their interests under one or more of nine headings; and, with the intention of keeping this information up to date, a further check is carried out during the preparation of a membership list.

The headings are:

- A General.
- B Metals.
- C Rubbers, polymers, polymer solutions, fibres.
- D Emulsions, suspensions, pharmaceuticals, paints, printing inks.
- E Glasses, ceramics.
- F Lubrication, friction, wear, oils, greases.
- G Building and road materials.
- H Confectionery, doughs and other foodstuffs.
- I Biorheology.

Group A is now divided into (i) Theory, (ii) Experimental.

Most members list from one to five groups of interests, but approximately 20 British members, and much higher proportion of those outside Britain, give no details. The blank occurs probably because the application form was not fully completed, but could arise because that member's interests were not included in the standard list. In many cases it was possible to use external evidence to fill in the blanks; although these insertions were known to be correct, they may not have covered *all* that person's interests.

Breakdown of membership by interests is given in Table 4. Comparison between 1966 and 1963 data enables the rate of growth of each group to be calculated. (The 1959 list did not tabulate interests in the standard manner, and so further comparisons are not possible without the expenditure of considerable effort.)

The two largest groups of closely defined interests are C (Polymers, rubbers, etc.) and D (Emulsions, suspensions, etc.). Each of these groups is of similar size, and has increased by 40% between 1963 and 1966. Between them these two categories account for 43% of the total member interests, or 63% if Group A (General) is omitted.

The small size of the remaining specialised groups of interest is rather alarming, and probably accounts for the failure of two recent conferences.

It is disturbing to find that the number of members interested in the rheology of foodstuffs is slowly declining, and that there has been no increase in the number interested in metals. The rise of interest in lubrication and wear is very disappointing considering recent developments in this field.

Group A (General) has more than doubled in size between 1963 and 1966, and a cursory examination shows that "General" may mean different things to different people. This group was therefore examined in further detail, to investigate who was interested in general rheology, both as the only entry in the list of interests, and when listed with other interests.

The sub-division was made into: University, (i) theoretical, (ii) experimental (a correct division often not being obvious); Managerial (being defined as manager or director in industry, or head of group or senior post in research institute); Industrial; Research Institute; and self-employed.

Table 5 lists members interested in Group A only, while Table 6 lists Group A plus other interests. The form of each distribution is of more significance than the exact numbers involved, due to the somewhat arbitrary nature of the selection procedure used.

A suggested interpretation of these figures is that rheologists interested only in category A tend to be theoreticians, whilst managerial grades interpret A in the wider sense of a general interest in many aspects of rheology.

The data for British members (1966) are rearranged in Table 7 to show the numbers of members indicating an interest, or lack of interest, in general rheology. These numbers may be expressed as percentages of either the totals of each type of occupation (that is university, managerial, or others) or the totals of each group of interest respectively. In analysing these figures, it might be thought, *a priori*, that university members would be more likely to be associated with general group A interest while members other than university and managerial would be more likely to be associated with interest in specific materials or phenomena of groups B to I. However, the figures show that although a large proportion (65%) of members with "other" occupation expressed no interest in general rheology and of those who expressed no general interest in rheology, 69% are members of "other" occupation, no such association may be said of university members and general rheology. Thus, although of those interested in general rheology alone 59% are university members, only 20% of university members are interested in general rheology only. In fact about half of university members are interested in general rheology as well as specific materials. It is gratifying to note that university members are not as isolated in their ivory towers as one could have first guessed.

If it is true that members who expressed no interest in general rheology are really not interested in rheological principles, this could well account for the lack of application of rheology to industrial processes, since these members are expected to be actively engaged in the workings of industries. The lack of application of rheology has of course been recognised by the Council and the Research Committee of B.S.R., who are attempting to encourage such work by the proposed award of the Gold Medal for applied rheological research.

The distributions of managerial members in each of the three groups of interests are roughly the same as their distribution in the total membership. This shows that managerial members are the least biased in their interests.

Finally in this part of the survey, Table 8 shows the known numbers of members holding posts of senior status (no account has been taken of the variation in meaning of the term "professor"). It would appear that in 1966 24% of British members and at least 17% of overseas members were in this category—implying (a) that salesmen of products for "top people" ought to invest in a list of B.S.R. members, or (b) that members have a duty to keep their list away from the eyes of such salesmen.

(c) Comparison with N.E.L. Survey

In September 1964, the National Engineering Laboratory published a survey of rheological research in Britain, made jointly with the British Society of Rheology.¹ A similar survey was made in 1966,

but because of the greatly increased size compared with that in 1964 the report has not yet been published.² The authors have, however, been supplied with pre-publication copies of diagrams listing the numbers of organisations interested in different types of materials and phenomena, from which it is possible to obtain an estimate of the number of organisations working in each B.S.R. classification of interests.

The basic data, extracted (with possible small errors) from the original bar charts are given in Table 9. Where applicable, equivalent B.S.R. groups are indicated. The headings "Agglomerated Solids" and "Powders or granular solids" in the charts of materials studied are not directly related to B.S.R. groups. However, using the full 1964 N.E.L. report the entries then appearing under these headings were subdivided into the appropriate B.S.R. classification. Assuming that the same proportionate distribution of interests occurred in 1966, the overall N.E.L. figures could then be converted into B.S.R. groups. This procedure leads to Table 10, where B.S.R. classification is used to compare numbers of B.S.R. *members* with numbers of *organisations* recorded by N.E.L.

An additional source of inaccuracy in Table 10 arises because "Friction, lubrication, etc." and "Biological phenomena" are listed under phenomena in the N.E.L. report. Although the numbers in these headings can be compared directly with B.S.R. groups F and I, it must be remembered that all entries under "Phenomena" have previously been included under "Materials," resulting in entries under the headings F and I occurring again in the table, distributed in an unknown manner between other groups. The two headings contribute, however, only about 10% of the total organisation-interests, and thus the form of the overall distribution will not be altered appreciably.

There is no appropriate heading in the N.E.L. survey (which deals with *organisations*) for a general interest in rheology, and "Idealised materials" can be compared approximately with the new B.S.R. group A (i) (Theory)—which is not included separately in the membership list. As a very rough guide for comparison purposes Table 10 therefore shows the number of B.S.R. members having interests in Group A only, and no other groups.

Despite its weaknesses Table 10 does enable the relative strengths of various groups within B.S.R. to be established. It confirms immediately that the Society is very poorly represented in the metals field—possibly not a surprising weakness, since there is no clear cut definition of how much of the science and technology of metals can be considered truly rheological, and the majority of metallurgists prefer to join societies of specialised interest rather than general bodies such as B.S.R.

The Society appears under-represented also in the biological field, but to what extent is undercertain, due to difference in nomenclature between the B.S.R. and N.E.L. surveys.

A further point worth noting is that food rheologists have not been distinguished accurately in the N.E.L. survey.

The 1964 N.E.L. survey listed 383 persons working in 226 establishments, an average of 1.7 persons per establishment. The number of "organisation-interests" (i.e. the total sum for all materials of interest) was 407, or 1.8 per laboratory.

Figures for 1966 show a total of 723 organisation-interests, which, when divided by 1.8 suggests that 400 laboratories in Britain are studying rheological problems. A rough check on the 334 B.S.R. members resident in Great Britain suggested that they were divided between approximately 240 establishments, which would imply that the Society is represented in approximately 60% of the appropriate British laboratories (assuming the recent N.E.L. survey to give almost complete coverage).

(d) Comparison with Board of Trade figures

Board of Trade figures are available on number of persons employed in various industries, and on the production³ and fixed capital expenditures.⁴ The labour force and production may be taken as an indication of the size of each industry, while the fixed capital expenditure may be taken as an indication of growth. Also figures are available on scientific research and development expenditures in different private industries.³ The industries concerned are grouped according to the Standard Industrial Classification in different orders. The orders that concern this analysis are the manufacturing industries as follows:

- Order III Food, drink and tobacco.
- Order IV Chemicals and allied industries (which includes oils, greases, pharmaceuticals, paint, printing ink and plastic materials).
- Order V Metal manufacture.
- Order VI Engineering and electrical goods (in which plastic materials are expected to be used).
- Order IX Metal goods not elsewhere specified.
- Order X Textiles (in which man-made fibres are included).
- Order XIII Bricks, pottery, glass, cement, etc. (which includes other building materials).
- Order XV Paper, printing and publishing.
- Order XVI Other manufacturing industries (which includes rubber and plastic fabricating).

These orders may be related to the groups of interests as follows: B with V and IX; C, D, and F with IV, VI, X, XV and XVI; E and G with XIII; and H with III. It was not possible for obvious reasons to obtain a finer sub-division between groups C, D and F with the related orders. The comparison between the 1966 British membership

and the B.O.T. figures for 1965 is given in Table 11. The total of 542 given for members is the value of Table 4 and while the totals for the B.O.T. figures refer to all manufacturing industries, the percentage figures given in parenthesis refer to these totals. In the B.O.T. sources the figures are sometimes given as sub-totals for several orders. In drawing up Table 11 these figures were divided equally between the orders concerned.

In the interpretation of the figures in Table 11, two factors should be borne in mind. Firstly, the B.O.T. figures were voluntarily contributed by individual firms and had been adjusted before publication by the B.O.T. Secondly, rheology does not play a part in certain industries in the orders considered and even if it does, it may not be an important factor in the industry. Thus it is not expected that the B.S.R. members' interest can be accurately compared with the B.O.T. figures, but rather that a rough guide may be obtained on how the Society may assist in the national economy.

Several things of interest may be noted from the figures in Table 11. There is good agreement between the percentage for B.S.R. members' interests with the B.O.T. figures for labour and for scientific research and development, excepting that (i) the B.S.R. percentage for groups E and G are much higher than the B.O.T. ones for Order XIII and that (ii) the combined labour of Orders IV, VI, X, XV and XVI is much lower than the B.S.R. interest in C, D, F. The reason for the first exception may be because rheology plays an important part in Order VIII and the reason for the second exception may be because the industries in Orders IV, VI, X, XV and XVI are the most up to date and are well mechanised and automated in operation. This picture of these industries is confirmed when the high expenditure on scientific research and development is noted.

While the B.S.R. figures for E and G and for C, D and F are consistently higher than the corresponding B.O.T. figures, the figures for B and for H are consistently lower than the B.O.T. figures. Since it is well known that rheology does play an important part in industries of Orders III, V and IX, it would appear that the Society is not well represented in groups B and H.

Conclusions

New members are joining the Society at an average rate of about three per month in Great Britain and one per month for those resident overseas (omitting Australia). N.E.L. data suggest that 40% of British laboratories undertaking rheological work as yet contain no member of B.S.R., and so, provided that new members do not resign after a few years, the Society membership ought to be capable of reaching a total of 500 for British residents alone. The proportionate increase in overseas membership could be very large, particularly if present plans for extending the usefulness of Rheology Abstracts become effective.

In particular, from comparison both with N.E.L. data and B.O.T. figures, it appears that the Society has a relatively small membership

in fields such as metals, foodstuffs and biorheology. There is good reason why the membership in the field of metals is low, but from the attendance at the recent London conference on the rheology and texture of foodstuffs and the general increase in interest in biorheology, it seems that these two fields could be successfully tapped for new Society members.

For an enlarged Society to maintain a solvent financial position, a large increase in sales to libraries of Rheology Abstracts would be needed—since profits on this journal represent a major part of the Society's income. Again this stresses the importance of continually increasing the coverage and improving the presentation of Rheology Abstracts. One of the ways that this could be done would be to identify the coverage and presentation of Rheological Abstracts more closely with the interest of the members. In this respect the existing B.S.R. classification needs to be modified and improved.

The analysis of the stated interests of members shows that group A (general) can signify a general interest in rheology, an interest in theoretical studies, or merely an interest not covered in another section. It is suggested that "Theory" be given a completely separate heading, and that there be an "X" category for fields not covered by other groups.

Pharmaceuticals might be worthy of a separate class, since the number of members having interests in these products has been increasing at a rapid rate. Similarly for the behaviour of powders or granular solids.

The existing B.S.R. nomenclature contains a mixture of both "materials" and "phenomena," with F (Lubrication, friction, wear, oils, greases) containing both headings at once. It would be an improvement to use a modified (possibly simplified) form of N.E.L. classification, with letters denoting materials studied and numbers phenomena. One could then tell at a glance which members were working, for example, on the theory of solid polymers, or on the visco-elasticity of road materials, or on the powder behaviour of foodstuffs.

One of the functions of the B.S.R. is to organise meetings and conferences at which members and non-members may meet and discuss problems of common interest. A few observations on this may be made based on the analysis of the B.S.R. membership.

In fields such as metals, foodstuffs and biorheology the Society is seen to have a relatively small membership. So that conferences dealing with topics such as these would be viable, it might be advisable for the Society to enter into a working arrangement with more specialist groups, and hold more joint meetings with other societies. Recent experiences bear out this point. A projected meeting with strong emphasis on solid behaviour had to be cancelled because of lack of support. But one on foodstuffs, held in conjunction with the Food Group of the Society of Chemical Industry was well attended.

Conferences may cover either principles or materials, and the former type, although probably of more fundamental significance, are liable to be unsuccessful due to lack of support. Table 7 suggests that 65% of members in British industry are interested only in their own specialist field (or perhaps, more important, their employers will not encourage them to attend conferences outside that field), and such information must be considered when meetings are planned.

An improved guide to conference planning would entail a full analysis of membership, rather similar to the N.E.L. survey, but with a greater break-down of the data. This form of analysis would be feasible, but would entail a much greater effort than the present preliminary attempt. The source data would need to be more complete and accurate than at present, and the volume of work involved would be worthwhile only if effective use was made of the final results.

As a final point of the membership analysis one may consider whether the Society is being administered in a manner representative of its members' interests. Policy is decided by an elected Council of 12 members, which at present contains seven representatives from universities, three from government establishments and research associations, and only two from industry. (Four members of Council, have, however, joined Universities only within the past few years, having previously gained experience in industry.) As a comparison only 35% of British members are from Universities, 17% from government establishments or research associations and 48% from industry. All members of Council are aware of this unbalance, but have been unsuccessful in trying to persuade members from industry to take a more active role in the Society's affairs. One must conclude therefore that many industrial members have either no spare time or else no interest in the way that the Society is organised. Since Council's decisions are not challenged at an Annual General Meeting it must be concluded that members are satisfied.

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- ⁴ **Board of Trade Journal**, December 9th, 1966, 1446.

Table 1. Employment of Members

	Year	University	Gov. Lab. or Res. Ass.	Industry	Total
British	1959	Not possible to group			231
	1963	67 (27%)	54 (21%)	132 (52%)	257
	1966	117 (35%)	57 (17%)	160 (48%)	334
Overseas	1959	Not possible to group			31
	1963	18	18	11	48
	1966	29	23	35	96
Australia	1959	Not possible to group			6
	1963	19	20	17	76
	1966	20	20	34	83
Total	1959	Not possible to group			268
	1963	104 (29%)	92 (26%)	160 (45%)	381
	1966	166 (34%)	100 (20%)	229 (46%)	513

(N.B. Totals in final column include members whose employment is not known.)

Table 2. Members Elected 1964-66

	University	Gov. Lab. or Res. Ass.	Industry	Total
Britain	38 (46%)	10 (12%)	34 (42%)	82
Overseas	5	5	11	21
Australia (not 1966)	1	1	9	11
Total	44 (39%)	16 (14%)	54 (47%)	114

Table 3. Membership by Year of Election

Year	Britain			Overseas			Australia			Total
	1959	1963	1966	1959	1963	1966	1959	1963	1966	1966
1940	24	11	11	—	1	—	—	—	—	11
1941	30	2	1	—	1	1	—	—	—	2
1942	11	6	5	1	—	—	—	—	—	5
1943	11	12	10	—	—	—	—	—	—	10
1944	13	9	9	2	—	—	—	—	—	9
1945	4	4	3	2	—	—	—	—	—	3
1946	10	7	7	1	—	—	—	—	—	7
1947	8	5	5	2	1	1	—	—	—	6
1948	14	7	7	1	—	—	1	—	—	7
1949	9	6	6	3	—	—	—	—	—	6
1950	5	6	4	—	—	—	—	—	—	4
1951	3	2	2	1	1	2	—	—	—	4
1952	10	6	5	1	—	1	1	—	—	6
1953	9	8	6	2	—	—	—	—	—	6
1954	7	5	5	1	1	1	—	—	—	6
1955	2	11	6	2	9	9	—	—	—	15
1956	11	15	11	1	6	5	—	—	—	16
1957	36	27	25	3	3	3	—	1	1	29
1958	24	13	10	4	4	4	1	2	2	16
1959	17*	15	10	4*	5	7	3*	4	4	21
1960		26	18		3	7		55	40	65
1961		24	18		7	6		21	10	34
1962		23	25		3	4		4	3	32
1963		7*	31		3*	12		7*	11	54
1964			43			12			8	63
1965			15			11			4	30
1966			26*			10*			?	36
Total	231	257	334	31	48	96	6	94	83	513

* Incomplete years

Table 4. Interests by Groups

1963										
	A	B	C	D	E	F	G	H	I	Total
Britain	77	17	89	93	9	21	21	17	13	357
Overseas	13	3	17	9	0	4	2	0	6	54
Australia	16	7	13	19	2	1	8	7	8	81
Total	106	27	119	121	11	26	31	24	27	492

1966										
	A	B	C	D	E	F	G	H	I	Total
Britain	167	19	125	129	13	23	28	15	23	542
Overseas	33	3	31	18	4	6	3	3	8	109
Australia	14	5	12	17	2	1	8	4	9	72
Total	214	27	168	164	19	30	39	22	40	723

% Increase 1963-66										
	A	B	C	D	E	F	G	H	I	Total
Britain	117	12	41	39	45	10	33	-12	77	52
Overseas	154	0	82	100	—	50	50	—	33	102
Australia	-13	-29	-8	10	0	0	0	-43	12	-11
Total	102	0	41	35	72	11	26	-8	48	47

Table 5. British Members Listing Group A Alone

	University		Managerial	Industry	R.A., etc.	Self-employed
	Th.	Exp.				
1963	10	6	4	5	1	1
1966	16	7	6	6	3	1

Table 6. Members Listing A plus Other Groups

1963

	University		Managerial	Industry	R.A.	Self-employed
	Th.	Exp.				
Britain	11	17	23	18	4	2
Others	2	8	6	4	5	—

1966

	Th.	Exp.				
Britain	21	34	23	33	15	2
Others	5	11	7	7	9	—

Table 7. Interest in General Rheology

(a) Analysis according to interest in each of the occupations

	University	Managerial	Others	Total
Group A alone	23 (20%)	6 (14%)	10 (6%)	39 (12%)
A + Other Groups	55 (47%)	23 (54%)	50 (29%)	128 (38%)
Other Groups only	39 (33%)	14 (32%)	114 (65%)	167 (50%)
Total	117 (100%)	43 (100%)	174 (100%)	334 (100%)

(b) Analysis according to occupation in each of the groups of interest

	University	Managerial	Others	Total
Group A alone	23 (59%)	6 (15%)	10 (26%)	39 (100%)
A + Other Groups	55 (43%)	23 (18%)	50 (39%)	128 (100%)
Other Groups only	39 (23%)	14 (8%)	114 (69%)	167 (100%)
Total	117 (35%)	43 (13%)	174 (52%)	334 (100%)

Table 8. Members with Senior Status

	Britain	Others
University Chair	19	15
Dept. Head or Senior Post in Gov. Est. or Res. Assn.	19	6
Manager, or Senior, in Industry	43	9
Total	81	30
% of Total Membership	24%	17%

Table 9. Number of Organisations having Rheological Interests
(Extracted from 1966 N.E.L. Survey)

(a) Materials

	BSR Group	University	Gov. Lab. or R.A.	Industry	Total
Glasses	E	15	6	1	22
Idealised Materials	A(i)	32	4	4	40
Metals and Alloys	B	45	16	7	68
Agglomerated Solids	—	43	18	23	84
Powders, Granular Solids	—	39	16	35	90
Molten or Dissolved Polymers	C	49	12	43	104
Solid Polymers	C	59	23	43	125
Multiphase "Liquids"	D	69	45	76	190
(b) Phenomena					
Friction, Lubrication					
Abrasion	F	7	2	4	13
Biological	I	38	18	7	63

Table 10. Interests of B.S.R. Members in Britain Compared with Organisations in N.E.L. Survey (see text for explanation)

B.S.R. Group	Organisations (N.E.L.)	B.S.R. Members
A	(68)	167 (39 A alone)
B	94	19
C	250	125
D	236	129
E	31	13
F	19	23
G	31	28
H	4	15
I	66	23

Table 11. Interest of B.S.R. Members in Britain Compared with B.O.T. Figures

B.S.R. Group	B.S.R. Members	B.O.T. order	Labour (thousands)	Production (thousand units)	Fixed capital expenditures (£ million)	Scientific research and development expenditures (£ million)
B	19 (4%)	V, IX	1079 (5%)	14.3 (11%)	176.0 (15%)	19.5 (4%)
C, D, F	277 (51%)	IV, VI, X, XV, XVI	4113 (17%)	52.7 (40%)	375.9 (32%)	218.0 (49%)
E, G	41 (8%)	XIII	323 (1%)	4.2 (3%)	44.0 (8%)	5.3 (1%)
H	15 (3%)	III	783 (3%)	10.4 (8%)	164.8 (14%)	13.8 (3%)
Total	542	Total of manufacturing industries	24196	131.9	1176.1	446.4

A PHENOMENOLOGICAL APPROACH TO MECHANICAL PROPERTIES

Imperial College, London, January 5th-6th, 1967

The symposium was organised jointly by the Department of Mechanical Engineering, Imperial College, and the National Gas Turbine Establishment. It is reported in some detail since the subject is one that has aroused considerable interest amongst certain members of the Society.

Introduction

The deformation behaviour of real solids is interpreted generally either in terms of model systems (e.g. springs, dashpots and viscoplastic elements) or by using methods such as those of continuum mechanics to develop empirical relations between the measured variables. In either case extrapolation of long term properties from short term data may be an unwarranted procedure.

Complex alloys, for example the materials employed in gas turbines, do not appear amenable to treatment in terms of a simple model, yet it is of the utmost importance to be able to predict their long-term mechanical performance. As a means of approaching these difficulties A. Graham and K. F. A. Wallès of the National Gas Turbine Establishment have developed a phenomenological treatment based on a combination of the Andrade creep equation ($\epsilon - \epsilon_0 = at^{1/3} + bt$) with the Nutting-Scott Blair relation ($\epsilon = \psi \sigma^\beta t^k$). [In the above expressions ϵ represents strain, σ stress and t time; a , b , ψ , β and k are constants.]

Graham and Wallès consider the strain to be built up from a sum of terms each proportional to $\sigma^\beta t^k$, each term involving temperature through its own time-temperature parameter. Evidence suggests that a term with a given value of k is compound, and is associated with several values of β , resulting in the G-W equation,

$$\epsilon = \sum_k \sum_{\beta/k} C_{k, \beta/k} \sigma^\beta \phi^k, \text{ where } \phi = t |T' - T|^A$$

The values of k form the series $\dots, \frac{1}{9}, \frac{1}{3}, 1, 3, \dots$, and the values of β/k the series $0, 1, 2, 4, 8, \dots$. Generally no more than two or three k values are required to fit experimental data. The critical temperature T' is determined experimentally, and is found to be constant for any given β/k . In all cases a value of A of ± 20 is found acceptable, the sign depending on whether T is above or below T' . It is claimed that $C_{k, \beta/k}$ remain constant, for any given path of loading, with stress, strain, time and temperature, thereby enabling predictions of long-term performance to be made from experiments carried out over a relatively short time range. A G-W type analysis appears applicable to materials as distinct as complex metal alloys and milk gels, suggesting some overall regularities in rheological properties.

Full descriptions of the G-W equation and its applications have been given mainly in publications having a limited circulation, and thus to give a wider forum for discussion, enabling arguments to be aired both for and against the theory, a symposium entitled "A Phenomenological Approach to Mechanical Properties" was held at Imperial College on 5th-6th January, 1967. It was encouraging that the 60 participants included not merely representatives of the industrial and academic fields, but both engineers and physical scientists from each sector.

The Symposium

Papers presented by Mr. Graham and Mr. Wallis outlined the development of the theory, paying particular attention to recent applications to scatter in properties, and history and path of loading.

Initial studies had indicated the need for additional exponents in the Andrade equation, and for a time-temperature parameter varying at a greater than exponential rate. Comparisons of creep and hot fatigue data then gave β/k values which formed a simple series, with the time-temperature parameter depending on these values and not k alone. Components of the total creep which varied differently with changes of temperature could then be distinguished. Analysis was simplified because for any particular application only a few terms of the full expression were required.

The theory predicted a singularity in the time-temperature parameter at T' . It was significant that experimental tests had shown structural metallurgical changes, and variations in thermal expansion coefficient, occurring in the appropriate temperature region.

Mr. Graham stressed, both in his paper and in subsequent discussion, that the theory was based on many different experiments on a large number of materials. A power series with arbitrary exponents was tried; the regularities of the exponents appeared from studies of collections of data. It was unfortunate that generally available data rarely covered an adequately wide range of variables for a definitive check of the theory, but a thorough, highly satisfactory, test had been made in a collaborative study of a complex alloy steel.

Differences in sample behaviour both between and within batches of material necessitated a statistical treatment of results. The G-W equation fitted the data within the limits of scatter, enabling families of curves to be plotted, which could then be used for extrapolation purposes. On occasions the scatter had a multimodal distribution, particularly in regions sensitive to stress and temperature changes. Although an explanation of this form of distribution could not at present be given, it was clear that design engineers should avoid regions of this type. [During subsequent discussion it was reported that bimodality occurred in the cumulative fatigue of copper at the change-over from inter- to trans-crystalline cracking.]

G. P. Tilly (N.G.T.E.) next discussed strain and rupture behaviour under cyclic stressing. For triangular stress pulses the Nutting-Scott Blair equation was applicable over a wide range of temperatures, and the time-temperature parameter had been used successfully for the analysis of rupture data. The application of stress pulses of other shapes, and a combination of static and cyclic stress was also considered. Predictions of time-hardening and strain-hardening methods were inadequate, but a modified life-fraction treatment was found satisfactory.

An electron microscope examination of samples of H46 steel used in the N.G.T.E. collaborative programme was described by B. Hicks (Lucas G.T.E., Burnley). Significant changes in the distribution of rod-like carbide precipitates were reported at temperatures of 575°C and 650°C, which were close to the values of T' found for this steel.

G. D. Branch (Electrical Res. Assoc.) doubted, however, the significance of these observations. He had examined similar samples heated for times up to 30,000 hours, and found that the changes described by Hicks occurred at lower temperatures given longer treatment times.

P. W. H. Howe (N.G.T.E.) then presented a theoretical basis of power laws of creep. Although the average internal stress in a deforming material equals the applied load, local maxima in internal stress cause creep deformation. The relation between the maxima of combinations of natural modes of stress fluctuation and their average value involves the logarithm of the number of modes in the combination. If the number of modes is regarded as a probability distribution its logarithm is a function of strain energy, which is itself proportional to stress squared. Creep deformation is thus shown to be related to stress through a power law; expressions can be derived both for primary and tertiary creep, and if a succession of processes is considered—each taking place in a region already undergoing an earlier process—a set of exponents is obtained resembling those in G-W correlations. Dr. Howe's approach is a most interesting development, and appears worthy of further study.

The redistribution of non-uniform stresses in a turbine blade containing temperature gradients was described by J. M. Clarke (N.G.T.E.). The importance of the ratio between the sensitivities of creep rate to stress and temperature was considered, and its numerical value was compared with the coefficient relating temperatures and thermal stresses. A model for primary creep based on the decreasing range of internal stresses was described, but some of the conclusions drawn seemed a mixture of special pleading and coincidence.

A contrast to the G-W approach was provided by the T. Ll. Richard (Aston Univ.), who demonstrated that an electrostatic model of a f.c.c. metal, in which a single crystal was assumed to consist of alternating sheets of positive ions and electrons, was capable of

yielding a non-linear stress-strain curve, and accounting for creep deformation. It was unfortunate that insufficient time was allotted for this paper, since the method of presentation forced upon the speaker made his reasoning difficult to follow.

Dr. W. J. Harris (Bristol Siddeley) criticised the paper, insisting that an electrostatic cohesion theory was not adequate. He suggested that compressive tests would show up the model's shortcomings.

The second part of the symposium consisted of a discussion of applications of G-W theory, when both advantages and weaknesses of the method were considered.

In an introductory paper Dr. Harris stressed the difficulties involved when translating the results of laboratory tests to the life of actual components. (Two theories might predict values for the life of a component differing by a factor of three. If the low estimate were correct the component would be completely uneconomic.) Some creep rupture experiments on notched steel samples were then discussed in some detail. The notch strengthening factor had been calculated using G-W theory; a critical temperature region where notch weakening occurred was associated with a bimodal scatter distribution.

The paper concluded with a survey of areas in which the application of G-W theory should be investigated, stress being laid on the importance of understanding fundamentals, and on using an alloy whose physical metallurgy was well known.

A report by W. Barr (S. Scotland E.B., formerly C.E.G.B.) of the application of G-W analysis to four austenitic steels was of diminished value, since the work had been brought to a premature conclusion. In the subsequent discussion Professor Alexander confessed himself somewhat perturbed by the need for multimodality, since for a mathematical expression to be of practical use to a design engineer it must have relative simplicity.

Professor Alexander and G. A. Webster (Imperial College) next discussed the application of G-W theory to the deflection of beams and columns subjected to simple stresses. Using the concept of skeletal stress, deflections were obtained in terms of a scaling factor times the G-W expression. Theory and experiment agreed well for uniform structures, and moderately well for composite columns. When buckling was restrained the scatter was very large (might multimodality be needed?), and no success was obtained with three-dimensional buckling because of mathematical complexities.

D. Warren (Bath Univ.) remarked that he regarded the advantages of G-W theory in interpolation and extrapolation from fixed time tests as self-evident, and he therefore dealt with some difficulties involved with other uses. In variable stress and temperature experiments, particularly when plastic and anelastic components must be separated, the large number of coefficients required entails the use of very fast computers. The computational effort becomes enormous in

complex structures (e.g. aircraft spars) where the axial stress is varying.

This type of complexity was further illustrated by E. Smith (Newcastle Univ.), who described the slow nature of the point-by-point theoretical analysis required in the design of a cylinder subjected to varying internal pressure and temperature.

Comments

The value of the meeting, and the manner in which the interest of participants was held, was demonstrated during the discussion periods, which, although totalling more than four hours, were inevitably too short.

Papers were reasonably well presented, except for the tendency to compress too much information either into the given time, or a single lantern slide. Fortunately the latter failing was not of lasting importance, because of a feature worthy of imitation at other symposia. Experimental evidence for G-W theory was assembled on a dozen large boards standing outside the lecture theatre, and speakers could refer to this permanent display when briefly showing slides of their data.

The meeting demonstrated effectively that G-W analysis can provide a practically useful method for extrapolation of mechanical properties of a wide range of complex materials. When, however, the method is applied to the response of such materials to non-simple stress patterns, an excessively large amount of computation may be involved. Further work is required, along the lines suggested by Dr. Harris, in relating the features of G-W theory to the atomic processes responsible for observed deformations—but Dr. Howe's paper gave an encouraging theoretical approach.

It was rather disappointing to find that no fundamental objections to G-W theory were made at the meeting, since some physicists are known to accuse the theory of finding regularity where none exists. The symposium consisted to a large extent of preaching to the (at least partially) converted, and disagreement between theory and experiment tended to be blamed on inaccurate or inadequate data. It must be stressed that critics were invited to the meeting, and the organisers would have welcomed hearing their views.

Possibly these critics were unaware of the symposium, although it was widely advertised, or else were unable to attend. Space is therefore offered to any member wishing to comment on the phenomenological approach to mechanical properties propounded by Mr. Graham and his colleagues.

(I have copies of several of the papers presented at the meeting, together with a list of other relevant publications. These may be borrowed on application.)

D. W. HADLEY.

MISCELLANEA

Members will be pleased to hear that they are now part of a charitable institution. The Society's application for registration as a charity was accepted in December 1966, therefore profits on publications and conferences accruing since that date will not be liable for taxation. The registered number of the Society is 249967.

The Editor of "Rheology Abstracts" has received several suggestions for new journals to be covered, but further suggestions are still welcome. Schemes for improving "Rheology Abstracts" are under active consideration, and it is interesting to note that "Physics Abstracts" is also planning improvements in its indexing systems.

A further possibility has arisen for reduced rate air fares to Japan for the International Conference on Rheology in October 1968. Provided that a minimum of 15 passengers (all members of the Society of six months' standing) wish to make the trip, a fare of £321 17s. 0d. can be obtained, compared with the normal economy class return fare of £459 16s. 0d. Any member who might be interested is asked to contact the Editor.

Not all scientific meetings of relevance to rheologists are sponsored by this Society; in fact many meetings of interest are arranged either by academic institutions or by *ad hoc* committees. It has been decided, therefore, to report, whenever possible, the proceedings of such symposia in this Bulletin. The Editor would welcome reviews of meetings which may be of interest to some members, and to initiate this new venture has himself contributed the first article.

In addition to subsequent reviews of symposia it would be helpful to publish advance information. Any member who knows of a meeting dealing with some aspect of rheology is asked to send, as early as possible, an announcement for publication in the Bulletin.

Review articles on any aspect of rheology are required for publication in the Bulletin. Articles may be between 1,000 and 5,000 words in length, and can contain up to six illustrations. Authors will receive 25 reprints, and may purchase additional reprints if needed.

MEN WHO KNOW ABOUT FLOW

BY ALAN HAYWARD (N.E.L.)

The article below was written at the request of the Central Office of Information for publication in newspapers overseas; its object was "to boost the image of Britain in foreign countries." An insistence that it be aimed at a readership comparable with that of the "Daily Express"—whose readers, it is fairly safe to assume, have little knowledge of tensors—posed something of a problem. Members might possibly be amused by the results.

We can all feel for the exasperated diner who cried,

“When I shake the ketchup bottle,
None’ll come—or else the lot’ll!”

Without realising it, he was grappling with a problem on the frontiers of science. The laws controlling the way things flow (especially gooey things like ketchup) are extremely complex, and a whole new branch of science called “rheology” is devoted to unravelling those laws.

Three hundred years ago everything looked delightfully simple. Sir Isaac Newton had studied the flow of liquids and propounded the simple law, that the harder they were pushed the faster they would flow. “Push a liquid twice as hard,” said Newton in effect, “and it will flow exactly twice as fast.”

For two centuries everyone was completely satisfied with Newton’s law. It was known to work with oil and with water, and people assumed that it was as universal as his other famous laws, about gravitation and motion.

Disobedient Liquids

It was not until the twentieth century that scientists smelt a rat. Many liquids were discovered which positively refused to obey Newton’s law, but which did all sorts of unpredictable things when you pushed them.

It was found, for example, that a class of liquids called “thixotropic” gradually grew thinner as they flowed. Like a new car being run in, they ran more easily after they had been running for some time.

For a few years not much practical use was made of this discovery. Then someone discovered how to put thixotropic liquids into paint, and a popular new product was born. With the introduction of non-drip paints, the new science of rheology had made its first big impact on the man in the street.

A curious class of substances which are neither solid nor liquid but something between the two was discovered by Professor Bingham in America. Bingham substances refuse to move at all when you push them gently, but when you increase the amount of push beyond a certain limit they move quite easily. Ketchup, of course, comes in this class, so does toothpaste, and many other pastes and slurries.

When coal is mixed with water it becomes a Bingham substance. Now that scientists understand the behaviour of Bingham substances it is possible to pump coal from place to place through a pipeline, just as if it were oil.

Liquids that Bounce

The strangest liquids of all are called viscoelastic. These liquids suffer from chronic homesickness. When you push them they move

like any other liquid, but as soon as you stop pushing they start to go back where they have come from, just as if they were full of invisible elastic bands.

The famous "potty putty," which is made from silicones, is in this class. You can mould it between your fingers, just like ordinary putty. But if you drop it, it will bounce like a rubber ball. And if you leave a lump of it lying about, it will run all over the place like treacle.

Many liquids of great industrial importance are viscoelastic. Among them are molten rubber and molten plastics. When these are moulded or extruded into hot-water bottles, or hoses, or 101 other articles, the elastic spring-back of the liquid can cause all sort of defects if it is not properly allowed for.

World Wide

In a number of countries there are national societies of rheology, to cater for scientists working on flow problems like these. The British Society of Rheology is one of the two largest, with members in Britain and in about 20 other countries from Nigeria to Japan. By swapping ideas its members are often able to advance the state of knowledge in fields far away from their own.

Not far from London, Dr. Scott Blair of the National Institute for Research in Dairying is a world authority on the spreadability of butter and cheese. A few miles away from him, at the National Gas Turbine Establishment, Mr. A. Graham is studying the way metals deform when they are stressed.

Although you might not think there is much in common between steel and cheese, these two members of the Society have formed a fruitful partnership. The same mathematical equations can be applied both to the minute movements of the steel in a turbine casing, and to the flow of cheese under a knife.

Thus, through their common interest in rheology, the metallurgist and the dairying expert have been able to help each other in their own specialised fields.

From Mud to Blood

Dr. Whitmore of Nottingham University is a mining engineer. It is part of his job to know how to pump muddy liquids through pipes.

It occurred to him that blood flowing along a human artery is very like a scale-model of mud flowing along a pipe, with red and white corpuscles taking the place of grains of dirt. He was able to apply his specialised engineer's knowledge to this new field of "human engineering," and now doctors in many countries look to him as an authority on the flow of blood.

Another prominent member of the Society is Professor Weissenberg of the Royal Institution. His theory of viscoelastic flow has been used for years in the development of flamethrowers and of machinery for forming plastics.

But recently a more humane use has been found for his discoveries. They are now helping medical men to understand the workings of the joints of the human body, which depend upon the remarkable flow properties of Nature's own lubricant—the synovial fluid surrounding every joint.

Because rheology is a young science there are almost certainly many interesting discoveries waiting around the corner, especially in the medical field.

Who knows? Rheologists may one day even succeed in giving the world a ketchup that comes out of the bottle without shaking!

JOINT MEETING WITH S.C.I. (Oils and Fats) GROUP

A joint B.S.R.-S.C.I. evening meeting was held in London on November 16th, 1966. Because of short notice a general circulation of members was not possible, and only a few B.S.R. members attended.

P. W. Heaps (Spillers Ltd.) described some "Rheological studies on mechanical factors affecting dough development." Rheological tests on wheat flour doughs confirmed the existence of a definite level of work input to give optimum dough development for any one flour. The results suggested the existence of an optimum rate of work input for producing the most stable dough and the best bread. Rheological parameters were then compared with baking performance.

The second paper, by P. Sherman (Unilever) discussed "The rheological properties of fats and allied materials." Emphasis was laid on low stress techniques, such as the parallel plate visco-elastometer and viscometry. Physical parameters obtained by these methods could then provide information about the gross properties of a material.

ANNUAL CONFERENCE 1967

This year's meeting will be held at The Royal Military College of Science, Shrivenham, from September 19th–21st, on the subject of "Non-Newtonian Flow Through Pipes and Passages."

Intending contributors should send a synopsis, not more than 200 words, to Dr. M. F. Culpin, 8 Broadway, Pontypool, Monmouthshire, before May 1st.

As an experiment a short period during the Annual Conference will be set aside for the delivery of brief Progress Papers. The object is to give an opportunity of reporting interesting developments in current work, without the need to wait for a conference on an

appropriate theme. Progress Papers may therefore deal with any aspect of rheology, so long as the material is new and previously unpublished. A *maximum* of 15 minutes will be allowed for delivery, to be followed by a short period for discussion.

Members wishing to submit a progress paper should contact Dr. Culpin as soon as possible, but subject to the availability of space, synopses of these papers will be accepted up to the end of August.

[Personal experience suggests that even if the scientific sessions do not cater for one's interests a stay at Shrivenham is worth while purely from the gastronomic viewpoint.]

RHEOLOGY IN FRANCE

Professor Markus Reiner has accepted an invitation to become an Honorary Member at Groupe Français de Rhéologie.

At an afternoon meeting of G.F.R. on February 15th, M. V. Tuong presented a paper "Sur le passage de régime harmonique au régime transitoire très lent." Numerical and graphical methods were used to obtain relaxation and creep functions from experimental curves.

The Annual Conference of G.F.R. in June will discuss "Recent progress in the study of second order effects." At least one paper will be presented by a British rheologist.

The Ninth Study Session of L'Association Scientifique de la Précontrainte will take place in Paris, May 29th-31st, 1967. Further details can be obtained from L'Institut Technique de Bâtiment, 9, Rue La Pérouse, Paris, 16e.

FRENCH RHEOLOGICAL TERMINOLOGY

Literal translations of the first 46 definitions approved by the Council of Groupe Français de Rhéologie were given in Bulletins (3) 1965, and (3) 1966. A further instalment is given below. Comments may be made either to the Editor, or to M. B. Persoz, Groupe Français de Rhéologie, 68 Boulevard Saint-Michel, Paris 6e.

47. *Ecoulement* (Flow). The deformation process characterised by the absence of a privileged macroscopic configuration tending to re-establish itself after the removal of stresses; the stress may depend on the current strain rate, the time and the history of the deformations, with these deformations being measured from the current state.

Examples: the flow of a fluid; the flow of a solid above the yield point, provided that there is no hardening. [See definition 36 "*écrouissage*" (a)—Ed.]

48. *Viscosité* (Viscosity). Physical property implying that the stress depends on strain rate.

49. *Viscosité pure* (Pure viscosity). The case where there exists, at a given temperature, a doubly unique relation between the stress tensor and the strain rate tensor and where the two tensors become zero simultaneously.
50. *Coefficient de viscosité apparante* (Coefficient of apparent viscosity). The ratio between stress and the corresponding strain rate (that is to say the strain rate which multiplies the stress in the expression for the power per unit volume).
51. *Coefficient de viscosité différentielle* (Coefficient of differential viscosity). The ratio between an infinitesimally small increase in stress and the corresponding increment of strain rate.
52. *Viscosité newtonienne ou normale* (Newtonian viscosity). The case where the coefficient of differential viscosity is independent of strain rate and time (at a given temperature and pressure). In the contrary case the viscosity is said to be abnormal or non-newtonian.
53. *Ecoulement exclusivement visqueux* (Exclusively viscous flow). Viscous flow, however small the stress deviators may be.
54. *Ecoulement plastique* (Plastic flow). Flow produced only when stresses become greater than a threshold (cf. 33, yield point). The flow is called visco-plastic when above this threshold of flow the stress tensor depends on the strain rate tensor.
55. *Ecoulement de Bingham* (Bingham flow). The particular case of visco-plastic flow characterised by a proportionality between the excess of the stress above the yield value and the corresponding strain rate. The coefficient of differential viscosity is constant.

In Bulletin (3) 1966 comments were made concerning some of the earlier definitions. A reply has been received from M. Persoz regarding these comments, and will be published in the next issue.

THE (U.S.) SOCIETY OF RHEOLOGY

Starting with Volume 11, Transactions of the Society of Rheology will be published quarterly. Papers earlier presented at a meeting of the Society will in future be subjected to careful checking at the proof stage before publication.

The Fourth Winter Meeting was held at Santa Barbara from February 6th-8th, 1967. Following an invited lecture by D. T. Griggs (Univ. of Cal., L.A.) on "Mechanisms of deformation of rocks and minerals at high temperatures and pressures," were sessions on: Thermodynamics; Polymer melts and concentrated solutions; Bulk polymers; Continuum mechanics of non-newtonian fluids; Polymer solutions and suspensions; and General rheology. (The Bulletin Editor has available for loan a set of abstracts of the papers presented.)

A symposium on Block Copolymers is planned for June 5th at Cal. Tech., Pasadena. The papers will include review lectures as well as discussions of recent advances. Further information from N. W. Tschoegl, Cal. Inst. Tech., 1201 East California St., Pasadena, Cal. 91109, U.S.A.

MEETINGS ON GLASS TECHNOLOGY

A paper on "Refractory Wear" will be presented at Stirling on May 2nd, 1967.

A symposium on Glass Melting Processes will be held at Stratford-upon-Avon from May 10th-12th, 1967. Contributions include papers from Czechoslovakia, France, and U.S.A. in addition to Britain.

The Eighteenth Annual Meeting of the International Commission on Glass, scheduled for Prague, September 14th-16th, 1967, will take the form of a symposium on Coloured Glasses.

Papers are invited for a symposium on Refractory Materials, arranged jointly by the British Ceramic Society and the Society of Glass Technology, to be held at Sheffield, April 2nd-4th, 1968.

The Eighth International Congress on Glass will be held in Imperial College, London, July 1st-6th, 1968. Included in the programme are review lectures, seminars, exhibitions and social events, together with tours and visits.

Further information on all the above meetings can be obtained from the Asst. Sec., Society of Glass Technology, 20 Hallam Gate Road, Sheffield, 10.

CHEMICAL ENGINEERING MEETINGS

The I. Chem. E. and the Netherlands K.I.V.I. are to hold a joint meeting in Amsterdam, October 16th-17th, 1967, to discuss "The Application of Automation in the Process Industries." Particular emphasis will be placed on practical experience gained, and work in progress will be related, wherever possible, to future process design experiments.

Another joint meeting of the Institution will take place in 1968 in conjunction with the German Verfahrens-Ingenieure. Brighton, April 24th-26th, will be the venue for a meeting on "The Engineering of Gas-Solid Reactions." Separate sessions will discuss characteristics, physical handling, technical design and performance, and plant experience. Suggestions for papers are invited.

Details of both meetings are available from The Institution of Chemical Engineers, 16 Belgrave Square, London, S.W.1.

THE BRITISH POLYMER PHYSICS GROUP

A meeting on "Orientation in Solid Polymers" will be held at Churchill Hall, University of Bristol, on April 10th-11th, 1967.

The Group's Third Conference will be held at Shrivenham on September 12th-14th, 1967. It is hoped to have sessions on Morphology, Molecular Structure, Mechanical Properties and Solution Properties of polymers. Persons wishing to submit a contribution in any branch of polymer physics should send an abstract (150 words) to Dr. I. M. Ward, Physics Dept., University of Britsol, before June 30th.

Rheology of Suspensions

A postgraduate course of five lectures will be given on Tuesday evenings, 6.30 to 8.30 p.m., commencing May 2nd, 1967. Mr. R. W. Whorlow (University of Surrey) will discuss general aspects of the subject, while Mr. C. C. Mill (P.A.T.R.A.) and Mr. T. R. Bullett (Paint Research Station) will discuss printing inks and paints respectively. Further details of these courses may be obtained from the Secretary (Short Courses), University of Surrey, London, S.W.11.

NEW MEMBERS

NAME AND ADDRESS	INTERESTS
A. Bax, A.N.C.F.T., C.I.W.M., Park House, Windlestone Park, Nr. Ferryhill, Co. Durham. Procter Dept. of Food and Leather Sci., The University, Leeds 2.	Confectionery.
D. F. Griffiths, B.Sc., 28 Eastgate, Aberystwyth, Cards. Dept. of App. Maths., U.C.W., Penglais, Aberystwyth.	Theory.
N. G. McCrum. Dept. of Engng. Science, Univ. of Oxford, Parks Road, Oxford.	—
G. W. White, B.Sc., A.R.C.S., 50 Curzon Road, Ealing, London, W.5. Lyons Cent. Labs., 149 Hammersmith Road, London, W.14.	General (Th. and Expt.), emulsions, suspensions, glasses, confectionery, biorheology.
G. Airoidi, L. in Chim., 15 Via Grossich, Milano, Italy. Montecatini-Edison Ist. Ric., Via S. Pietro, Bollate, Milano.	General (Th. and Expt.), rubbers, polymers, polymer solutions.
Prof. A. B. Metzner, Sc.D., B.Sc., 713 Greenwood Road, Wilmington, Delaware, 19807, U.S.A. Univ. of Delaware, Newark, Delaware, 19711	General (Th. and Expt.), rubbers, polymers, polymer solutions.
J. M. P. Papenhuijzen, Phys. Eng., Thomas à Kempisstraat 160, Vlaardingen, The Netherlands. Unilever Res. Lab., Mercatorweg 2, Vlaardingen.	General, polymer solutions, printing inks.
Prof. T. Salomon, 28 Rue des Renaudes, Paris 7e, France. Ecole Nat. Supérieure du Pétrole et des Moteurs, France.	Rubbers, polymers, emulsions, glasses, ceramics, etc.
J. G. Savins, B.S., 3928 Vanette Lane, Dallas, Texas, 75216, U.S.A. Mobil Oil Corp., Res. Dept., P.O. Box 900, Dallas, Texas, 75221.	General (Th. and Expt.), polymer solutions, biorheology.
M. van den Tempel, D. Tech. Sc., Coornhertstraat 66, Vlaardingen, The Netherlands. Unilever Res. Lab., Mercatorweg 2, Vlaardingen.	General, emulsions, suspensions, etc.

OBITUARY

Dr. Paul White, of Reading University, a founder member of the Society, died in January 1967 after a long illness.