

FLETCHER & CO.
Farnborough, Hants
ENGLAND.

BULLETIN



BRITISH SOCIETY OF RHEOLOGY

1973, Vol. 16, No. 2

CONTENTS

	Page
Foreword	i
Australian Branch, 1972-73 Council	ii
Computer Programs for the Treatment of Viscometric Data and Pipeline Design (D. C-H. Cheng and W. Whittaker)	15
Teaching on Shifting Grounds (R. S. Lenk)	21
Symposium on "Basic Rheology and its Applications in Industry" and "Rheology of Composite Materials"	26
Recent Publications:	
Principles of Plastics Extrusion	29
Multiple Transitions in Semi-Crystalline Polymers	29
A Review of Recent Publications on Polymer Melt Rheology	30
Future Meetings:	
The Society of Rheology Annual Meeting	30
Fundamentals of Design in Plastics	31
The Conservation of Materials	32
Recent Elections	33
Diary	34

Hon. Editor:

Dr. J. M. HOBBS,
Properties of Fluids Division,
National Engineering Laboratory,
East Kilbride,
GLASGOW, G75 0QU.



FOREWORD

The recent announcement that B.E.A. will allow 50 per cent. off the fare for wives accompanying husbands (or vice-versa) is most welcome. In time this could change the entire atmosphere of conferences. No longer would the dutiful husband need to forgo the pleasures of post conference excursions and hurry home to his adoring wife and devoted family. Instead, the whole pace of the trip could be slackened and, provided any children were safely boarded out with grandparents or aunts, it could become more of a holiday even if not exactly a second honeymoon.

The potential demand for this would, of course, need to be taken into account by the organising body. It would not do, for example, to have the isolated and almost monastic environment sometimes found in a conference centre or university campus. To keep the little women content while their partners discuss second normal stress differences or whatever, would need almost as much preparation as the meeting itself. A wide variety of shops and other places of interest should be within easy reach by day. In the evenings the scope of social activities could be widened to include perhaps a conference dinner-dance and so on.

Unfortunately B.E.A. do not promise any discount on other items of expenditure. By the time the ladies have renewed their wardrobes and been given a generous allowance for "incidentals", the "saving" on the fare has been spent many times over. Perhaps a fat expense account is the answer.

AUSTRALIAN BRANCH, 1972-73 COUNCIL

President: DR. P. U. A. GROSSMAN, C.S.I.R.O. Division of Building Research, Graham Road, Highett, Melbourne, Victoria.

Vice-President: MR. W. COPLEY, H. B. Selby & Co., 352 Ferntree Gully Road, Notting Hill, Melbourne, Victoria.

Secretary: DR. J. M. STEARNE, Footscray Institute of Technology, P.O. Box 64, Footscray, Melbourne, Victoria.

Treasurer: MR. G. GIBSON, Davis Fuller Adhesives, 98 Bromwell Road, Collingwood, Melbourne, Victoria.

Ordinary Members:

MR. N. CHILOV, I.C.I. (Australia) Research Department, Newson Street, Ascot Vale, Melbourne, Victoria.

DR. D. BOGER, Chemical Engineering Department, Monash University, Clayton, Melbourne, Victoria.

MR. R. VINEN, Footscray Institute of Technology, P.O. Box 64, Footscray, Melbourne, Victoria.

DR. R. FOX, I.C.I. (Australia) Research Department, Newson Street, Ascot Vale, Melbourne, Victoria.

MR. J. LUBBOCK, Dulux Australia, McNaughton Road, Clayton, Melbourne, Victoria.

COMPUTER PROGRAMS FOR THE TREATMENT OF VISCOMETRIC DATA AND PIPELINE DESIGN

D. C-H. Cheng and W. Whittaker

SUMMARY

This note describes a series of computer programs for the treatment of viscometric data. They are:

Program C26C,

for the tabulation and graphical display of raw data.

Program C26F,

for the assessment of the ageing of a sample of fluid.

Program C26H,

for the calculation and correction of end effects.

Programs C26D and C26E,

for the calculation of shear stress and shear rate when coaxial cylinders are used.

Program C26B,

for the calculation of shear stress and shear rate when the viscometer bob is used in an infinite field of fluid.

Program C08D,

for fitting the shear stress/shear rate data to a power law modified Bingham plastic equation and for the calculation of the best values of F_Y , K and n .

Reference is made to an associated program, C08E, for the calculation of pipeline flow characteristics and the tabulation and graphical display of the results.

All these programs are written in ALGOL for use on the ICL 1900 series computers.

The computer programs are primarily designed for the Contraves Rheomat Viscometers, but they may be readily modified for other similar viscometers such as the Haake Rotovisko and the Brookfield Synchroelectric viscometers. The program C08D accepts data from any viscometer.

INTRODUCTION

The need to use computer assistance in the treatment of results became apparent when the Contraves Rheomat-15 FC Viscometer was automated¹ and used in connection with the WSL pipeline design procedure.² In one of these exercises, 123 runs were made to investigate the instrumental effect (wall and end effects) and material pro-

perties (ageing and temperature and composition dependence), and involved about 7500 data points. Even with the aid of desk calculators, the numerical and graphical treatment of the data is tedious and time consuming. A suite of computer programs has, therefore, been written to carry out the calculations and to display the results graphically.

The programs are designed;

- (i) to process the raw data for visual inspection,
- (ii) to calculate and correct for end effect,
- (iii) to derive shear stress and shear rate values, and
- (iv) to fit the power law modified Bingham plastic equation and determine the best values of the parameters F_Y , K and n .

Graphical output of the results is obtained at each stage for a visual check of validity and consistency. A mark II version of a program for pipeline flow characteristics has also been prepared. Among its novel features is a graphical output of the pressure drop/flow rate relationship.

The viscometer programs are written for the Contraves Rheomat-15 Viscometer but they are readily modified to handle data from the Rheomat-30 Viscometer, e.g. the Haake Rotovisko and the Brookfield Synchroelectric Viscometers. The curve-fitting program accepts data from any viscometer.

In this note brief descriptions of the programs are given.

PROGRAM C26C: PRELIMINARY TREATMENT OF VISCOMETRIC DATA

Purpose

This program produces a table of the digital voltmeter (DVM) readings from the viscometer, calculates the mean-over-cycles at each speed and gives a graphical output of reading versus speed. Visual inspection of the graph will indicate whether any spurious data (such as that caused by jamming of the gear box in the viscometer) has taken place.

Method

The method is to sort the data into the appropriate order for tabular and graphical output. The latter is achieved by a procedure developed in this laboratory which uses the line-printer in place of the slower graph-plotter. The data points are plotted as characters and with more than sufficient accuracy. (Examples of outputs have been published elsewhere.³)

Input

The program accepts the data-logger tape from the automatic Rheomat-15 Viscometer.

Output

Table of DVM readings arranged by order of up- and down-cycle against speed; also the mean at each speed. Line-printer graph of readings versus speed, the former designated by alphabetical characters.³ The program also outputs a paper tape consisting of the mean DVM readings plus the relevant constants for inputs to program C26D.

PROGRAM C26F: AGEING EFFECT OF FLUID

Purpose

This program determines an ageing factor between the results of two viscometric tests carried out at different times (or under other conditions). The ageing factors obtained at different times may be extrapolated to zero time to provide a correction factor for ageing effects.

Method

The computer compares the corresponding DVM readings of two runs at each speed and order of the up- or down-cycle and calculates their ratio. The ratio is averaged at each speed and then averaged over all the speeds. If the ratios are sufficiently constant over the cycles and speeds, the mean overall cycle and speed is taken as the ageing factor.

Input

The program accepts two or more lengths of data-logger tapes from the automatic Rheomat-15 Viscometer.

Output

Two tables of DVM readings (as for Program C26C) followed by a table of ratios arranged by up- and down-cycle and speed; also the mean at each speed and the ageing factor. Line-printer graph of ratio versus speed.

PROGRAM C26H: END EFFECTS IN VISCOMETRIC DATA

Purpose

This program determines the end effects present in a set of viscometric data and corrects the data.

Method

Linear regression is used to determine the best slope and intercept of DVM reading versus height of viscometer bob at each speed. This provides the end effect corrected torque per unit length values required for shear stress and shear rate calculations. The 95 per cent. confidence limits are also calculated.

Input

The program accepts data-logger tapes from runs made with four different lengths of viscometer bobs.

Output

Tables of slopes and intercepts at each speed, together with the variance and the 95 per cent. confidence limits; also the end effect corrected DVM values appropriate to a standard bob length. Line-printer graphs of slopes and intercepts, with the 95 per cent limits, versus speed.

PROGRAM C26E: SHEAR STRESS AND SHEAR RATE (END EFFECT CORRECTED DATA, CO-AXIAL CYLINDERS)

Purpose

This program converts the end effect corrected DVM values from program C26H into shear stress and shear rate values.

Method

The program is an up-dated version of that published by Cheng and Davis,¹ in which the numerical differentiation is carried out by a least squares technique using the five-point parabola method.⁴ This gives a unique value for slope. The calculations of shear stress and shear rate are as for the previous program.¹ Smoothing of the DVM values is also carried out by using, as in the previous program, the method of fourth differences and a second set of shear stress and shear rate values are produced.

Input

Paper tapes manually prepared from the results of program C26H.

Output

Tables of shear stress and shear rate for the unsmoothed and smoothed data at each speed. These values are also output on a paper tape which can be used as inputs to program C08D. This will result in shear stress/shear rate graphs (flow curves).

PROGRAM C26D: SHEAR STRESS AND SHEAR RATE (RAW VISCOMETRIC DATA, CO-AXIAL CYLINDERS)

Purpose

This program calculates shear stress and shear rate from raw viscometer DVM readings. It is the same as Program C26E except that a lower limit is set for the DVM readings to be accepted. This is because readings less than a certain value are not meaningful due to the construction of the Rheomat Viscometer.

Method

As for program C26E.

Input

The data-logger tape from the automatic viscometer, or the output tape from program C26C, or others manually prepared.

Output

As for program C26E.

**PROGRAM C26B: SHEAR STRESS AND SHEAR RATE
(RAW VISCOMETRIC DATA, SINGLE CYLINDER)****Purpose**

This program handles data that have been obtained using the viscometer bob in an infinite field of fluid. (In practice, this condition is satisfied when the shearing zone of the sample does not extend up to the outer cylinder.)

Method

The calculations and numerical differentiation are the same as Program 626E, except that the shear rate is calculated using the equation given by Barton, Cheng and Higman.⁵ The same lower limit is imposed as that for program C26D.

Input and Output

As for program C26D.

**PROGRAM C08D: POWER LAW MODIFIED BINGHAM
PLASTIC CURVE-FITTING****Purpose**

This program fits the power law modified Bingham plastic equation

$$F = F_Y + KD^n$$

in which F is the shear stress, D the shear rate and F_Y , K and n are the material parameters, to a set of shear stress/shear rate data and determines the best values of the parameters.

Method

The method used is that of plotting $\log (F - F_Y)$ versus $\log D$, for various trial values of F_Y , until a straight line is obtained. The values for K and n are calculated from the linear regression line. Graph-plotting is accomplished with the standard ICL sub-routine and graph-plotter.

Input

The output tapes from programs C26B, C26D or C26E, or others manually prepared. Data from any viscometer are accepted.

Output

Table of input shear stress and shear rate and shear stress values are calculated from the fitted curve; also values of the best fit parameters. Graph of shear stress versus shear rate, with fitted curve drawn through the data points.

PROGRAM C08E: PIPELINE PRESSURE DROP/FLOW RATE CALCULATION

Purpose

This program calculates the pressure drop/flow rate relations for a specified range of pipe diameters and fluids.

Method

Program C08E is an up-dated version of that published by Cheng, Davis and Scarrow⁶ for the calculation of pipeline flow characteristics. The improvements include the determination and output of the transitional flow conditions.

Graphical output of the pressure drop/flow rate relation is obtained by using the standard ICL sub-routine.

Input

This consists of a data tape containing material parameters F_Y , K , n and density, pipe diameters, and upper limit of pressure gradient.

Output

Table of pressure drop/flow rate relations divided into laminar, transitional and turbulent regions, together with the Reynolds numbers and friction factors. Graph of the pressure drop/flow rate curves for the different pipe diameters.

CONCLUDING REMARKS

The programs described in this note are in constant use in Warren Spring Laboratory. The results of some recent work are described by Cheng and Whittaker,³ whose paper gives examples of the line-printer graphs of viscometric data and computer graphs of pipeline characteristics. Arrangements can be made for copies of the programs to be made available or for viscometric data to be processed at the laboratory.

REFERENCES

- ¹ Cheng, D. C-H. and Davis, J. B. *Rheol. Acta*, 1969, **8**, 161-73.
- ² Cheng, D. C-H. A design procedure for pipeline flow of non-Newtonian dispersed systems. *Paper J5. 1st Int. Conf. on Hydraulic Transport of Solids in Pipes*, Coventry, 1970.

- ³ Cheng, D. C-H. and Whittaker, W. Application of the Warren Spring Laboratory pipeline design method to settling suspension. *Paper C4. 2nd Int. Conf. on Hydraulic Transport of Solids in Pipes*, Coventry, 1972.
- ⁴ Lanczos, C. *Applied Analysis*. New York: Prentice-Hall, Section 7, Chapter 5, 1964, p. 316-324.
- ⁵ Barton, C. P., Cheng, D. C-H. and Higman, R. W. Explicit formulae for the rotating or translating cylinder when used in non-Newtonian viscometry. *Bull. Brit. Soc. Rheol.*, 1972, **15** (1), 10-17.
- ⁶ Cheng, D. C-H., Davis, J. B. and Scarrow, A. Flow of generalised Bingham fluids in straight pipelines. Paper to Instn. Chem. Engrs. Symposium, Salford, Dec. 1967.

"TEACHING ON SHIFTING GROUNDS"

R. S. Lenk

Polytechnic of the South Bank, Borough Road, London, S.E.1 0AA
Department of Chemistry and Polymer Technology

The title of this note allows of a number of interpretations. It is intended to deal with several of them:

- (1) The technology of change
 - (I) Production
 - (II) Design
 - (III) Teaching the technology of change
- (2) Shifting syllabuses
- (3) A changing student type
- (4) Change in student motivation
- (5) Changes in graduate requirements on the part of society.

(1) The technology of change

I. Those which are central to the study of overall changes occurring as a result of production processes.

When we talk about "steady state processes" we may observe no nett change in time in the process zone as such, but we *can* observe a diminution of raw material and an accumulation of end product. Non-steady-state processes in modern industrial production (which ideally excludes "one-off" products) possess an underlying dynamic which is itself subject to rate changes. This results *either* in runaway acceleration leading to explosion *or* in deceleration leading to stand-still and futility—unless rational process design is applied. This involves

- (i) the identification of the point at which an accelerating process is still fully under control within its safety limits—or at which a decelerating process can still be regarded as marginally productive;

- (ii) the termination of the process at this point;
- (iii) the initiation of a fresh process cycle on a continuous basis.

Taking a global view, such a continuous sequence of identical cycles may be regarded as a steady-state process after all, in the same sense as a perfect pearl necklace may be considered a homogeneous whole, despite the fact that it is composed of discrete constituent units: No *one* unit on its own—only the sum total of units collectively—makes sense. The same is true of the separate organs of a living organism or of the components of a complex machine in which the importance of the individual components—be they animate or inanimate—is obvious not just for their own sake, but equally for the sake of the harmonious functioning of the overall structure. Indeed this is true even of society itself!

It may, of course, be argued that, conversely, even the so-called steady state processes which are so characteristic of modern mass production can be analysed until a sufficient magnification in space and in time enables one to identify the unit processes of which the overall change is composed. That is to say—to identify the “pearls of the necklace” as, for example in the study of reaction mechanisms, of flow processes or of the mechanics of failure. There are few fields of modern mass production in which steady-state processes (in the widest sense) are as clearly epitomised than in the processing of plastics.

It is seen that the whole philosophy of observed change is geared to what is observable within the time scale available to the operator.

II. The second kind of drifting ground which comes within the ambit of the technology of change does not involve *production* processes at all. Instead it involves gradual or abrupt changes which result in a modification of components in the course of their functional life—usually the undesirable one of actual failure. Gradual changes may be observable as creep or stress relaxation. This implies that failure—when it eventually occurs—is *tough* rather than *brittle* failure. In the *absence* of significant creep or stress relaxation, abrupt changes are usually the result of some instability which has been imparted to the component during production or at the commencement of its functional life. For example:

- (i) The presence of a critical strain which has irreversibly damaged the fabric of the material and which will eventually result in catastrophic (*brittle*!) failure. In the absence of a stress-corrosive environment this failure may take a long time before it occurs, but by subjecting the specimen to specific stress-corrosive media it is possible to demonstrate within seconds or minutes the fate which would befall the component if it were left to function in its normal environment for some years. Once this correspondence has been empirically established it is even possible to make long term predictions as to the functional life of a component. Natur-

ally, other factors (such as temperature and production stresses which may not have been removed by annealing) are also involved here. This complex subject has received a great deal of attention in the last 10 years (vide numerous papers by J. Pohrt and others).

- (ii) The metastable condition of a supersaturated solution containing a "seed" of crystallisation nucleation. This includes supercooled liquids such as glass, where the process of crystallisation is commonly referred to as devitrification.

III. Having thus defined the shifting grounds of the technology of changes, let us now turn to the teaching which this requires.

So far the word "rheology" has not been mentioned. But my distinguished and discerning audience will have realised that the study of change itself, if allied to cause and effect, and if linked—as it needs must be—to a practical time scale, is nothing other than the *study of flow and deformation* which is the classical definition of "rheology".

The study of rheology in depth requires a basic knowledge of the mathematics of change—that is to say, of differential and integral calculus, and of vector and tensor manipulation. But the teaching of rheology does not *necessarily* require that every student commit himself to a study in depth. It all depends on the objective of each course. If the objective is severely limited by the time available, then the demonstration of the application of mathematical techniques must be subordinated to the aim of inculcating an appreciation of the underlying *philosophy* of change, it must also be subordinated to the need of evoking an understanding of the nature of specific materials of construction within the spectrum of the design properties which govern material behaviour during the production and during the functional service life of the product. The spectrum of properties ranges from "ideal elastic" as possessed by the "ideal solid" to the "ideal viscous" as possessed by the "ideal liquid". An ideal solid stores all applied energy and returns it without loss. An ideal liquid dissipates all applied energy and turns it into heat, with none of the input energy recoverable. By definition neither exists and all *real* bodies have both viscous and elastic attributes, that is to say, they are viscoelastic. Even undoubted "liquids" such as water have elastic attributes:

- Expt-demos: (1) Large hot-plate and water in wash bottle. Squirt on—watch dancing beads—"solid or liquid?"
- (2) Contrast: "Potty-putty" as a rubber, as a tough or brittle plastic and as a liquid!

There does, however, exist *one* unifying principle:

The principle that each reaction to a stress input requires a minimum time specific to each material, so that the imparted energy may be dissipated without causing catastrophic (i.e. brittle) failure in a material.

This minimum time is “the relaxation time” of the material. If the relaxation time is short relative to the experimental time scale, then the material can be seen to flow or creep. If it is long relative to the experimental time scale, then for practical purposes it may be regarded as a solid. The ratio of relaxation time to experimental (observation) time is known as the “*Deborah Number*” (Reiner). (Book of Judges: “. . . And the mountains flowed in the sight of the Lord . . .”) The observational time scale of the Lord extends, as everybody knows, over millions of years. Hence the Deborah Number of rock is evidently small, as far as the Lord is concerned, but it is large, as far as we are concerned. *We* can build on rock, because for our purposes it is solid enough. The Lord would not want to do so—but then he wouldn’t *need* to do so either!

Now for some other interpretations of “teaching on shifting grounds”: I must be brief here, but for what it is worth, may I throw open to discussion the following.

(2) **Shifting syllabuses**

Changing syllabuses necessitate changes in material coverage and presentation. Nowadays it is fashionable to change syllabuses ostensibly in a search for course improvement. Sometimes a contraction in hours aims at distilling the essence of existing material in order to make room for more new material elsewhere.

Sometimes it is purely experimental, at other times it is the result of whims on the part of individual course organisers or their committees, committees usually being worse offenders than individuals. (It has been said that a camel is a horse designed by a committee!). Most probably it is a manifestation of the phenomenon termed “future shock” (Alvin Toffler).

I am not opposed to change, seeing that it is, scientifically speaking, my bread and butter. But I am not so sure that I am always in accord with a proposed *rate* of change (acceleration) or a proposed *change* in the *rate of change* (the 3rd derivative of time). When it comes to the second derivative of time (acceleration), teachers are usually good judges after exchanging views with colleagues and successful courses are best left well alone. This is no plea for conservatism, only a reminder that change is not justified merely for its *own* sake.

(3) **A changing student type**

It is—and has always been—in the nature of the learning process that students look for simplicity. But the legitimate penchant for simplicity must not go so far as to tempt the learner to ignore complexities where complexities manifestly exist. This is certainly the case in the study of processes of change, or of rates of change, or of rates of change in the rates of change. The basic facts to which conceptualisation has to be anchored constitutes shifting ground. Of course, the

salvation lies in recognising that even shifting ground can, scientifically speaking, serve as a real and solid base at least for a period of time which is practically acceptable. This recognition leads to the discovery of unifying principles. The change in student type which has been accelerating in the second half of this century is caused by the increasing (and often subconscious) realisation that the discovery of unifying principles has to be achieved and experienced by each student individually. This is due to the fact that students are confronted with a rapidly changing learning situation which is entirely novel. In this learning situation "simple" answers have rightly become as suspect as the panaceas proposed by doctrinaire politicians. Students are developing a healthy skeptical attitude which is not content with apparent simplicity and which looks for underlying complexities in order to discover unifying concepts. This requires an *unprecedented* degree of maturity. There is evidence that such maturity is developing in the successive stages of students' courses.

(4) Change in student motivation

Academic courses have in the past been pursued for the sake of satisfying curiosity, for the purpose of ensuring a temporary existence of idle indolence with no intention of serious study, for the acquisition of status or for the meal ticket which was expected to go with a degree. The last two, so significant in post war Western society, have almost ceased to be of major importance today. Perhaps we are witnessing a return to the stage at which interest in the subject was the principal motivation.

(5) Changes in graduate requirements on the part of society

A change in demand as regards the quality of the end product, affecting, as it were, the social pressures on the teaching of scientific disciplines: At this time the "narrow specialist" (*so called!*) is passé. Today's starry-eyed bright boy is the more mundane generalist because he is supposed to be readily convertible at any stage of his career with a minimum of reprogramming and at the push of a button. Whether this is in fact *realisable* is exceedingly doubtful; whether it at all *desirable* even more so. True academics would regard a robot society in which transistorised brain implant units can turn a physicist into an instant chemist, biologist, economist, politician or captain of industry with the utmost revulsion. The potential appearance of a super-elite which owes its preferment to the widespread mediocrity which they arrogantly regard as universal excellence is scarcely more attractive.

In the end it may perhaps become generally accepted that the so called "demands of society" have no moral justification if they come into conflict with the natural indulgence of the individual in the academic pursuit of his choice for no better reason than the basic desire of Man to gain knowledge. For there *is* no better reason—it is the one thing that does not shift.

SYMPOSIUM ON "BASIC RHEOLOGY AND ITS APPLICATIONS IN INDUSTRY" AND "RHEOLOGY OF COMPOSITE MATERIALS"

Lunteren, April 26th and 27th, 1973

Some 91 delegates took part in this symposium which was held at the Congress Centre, "De Blije Werelt", situated in a picturesque wooded area a few miles north of Ede. Accommodation at the centre for the meeting was very good with a spacious lecture theatre and adjoining dining room and lounge complete with bar. Most delegates were allocated a separate room which contained twin beds, shower, etc. This was more than adequate although a few found the beds hard and the more enterprising ones contrived to improve matters using the spare mattress.

Early arrivals began on the Wednesday evening prior to the start of the meeting. After a wash and brush up, a meal in one of the local eating houses, they tended to congregate in the lounge for registration and informal discussion.

The meeting proper began the next morning with a short opening address by Dr. Heijboer, President of the Netherlands Society of Rheology. Dr. Heijboer welcomed the members from the Netherlands and visitors from various countries including Belgium, France, the United States and the United Kingdom. He extended a special welcome to Dr. Weissenberg, who was guest of honour. In conclusion, he formally introduced the chairmen for the four sessions of the symposium, the first of whom was Professor Lamb.

Professor Lamb's first duty was to introduce Dr. Heijboer to present the first paper on "Physical-mechanical characterization of plastics in view of their application". Having been brief in his opening remarks Dr. Heijboer had the benefit of an extra 10 minutes for his talk. He described a collaborative programme between R.A.P.R.A. and Central Laboratory T.N.O. to characterise plastics with the ultimate aim of making a compendium of their mechanical properties.

Many difficulties can arise in such work as in the Izod test for impact strength down to -200°C ! Because it was impracticable to cool the entire test apparatus, specimens had to be cooled and then tested as quickly as possible. A technique had been perfected to do this within two seconds of removal from the cooling vessel. It was evident that Dr. Heijboer and his colleagues had made a significant start towards their goal.

The second paper "A model approach to raw rubber processing" was ably delivered by Dr. van Es. He presented a tentative stress analysis of the flow of rubber in a rolling mill, making use of the Bird-Carreau constitutive equations. It was a good example of first

assuming a velocity distribution and then mapping the flow field in more detail by iteration.

To conclude the morning session, Dr. L. de Jong presented the paper "Viscoelastic analysis of pavement response under a moving load". This proved to be of wider interest than at first thought and may even have applications in the printing field.

After what was described as a Dutch coffee lunch, the second session began under the chairmanship of Dr. de Vries, secretary of the Netherlands Society. He introduced Professor Rogers of Nottingham University who gave a very clear exposition on "A simple continuum model for fibre-reinforced materials". The final points of this discourse were illustrated very neatly by the deft manipulation of a ship's curve which left the audience literally speechless.

F. M. Waals next gave an interesting paper on "Stiffness properties of oriented fibre composites and foams". This study was aimed at the theoretical prediction of effective stiffness of composites, but it was also applicable to anisotropic foams. At this point the effect of the Dutch coffee lunch must have worn off or delegates were eagerly anticipating the tea break as there was no discussion.

After being suitably refreshed we next heard Dr. Street present "Time dependent flow and rupture properties of metals containing strong fibres", describing work done at N.P.L. in collaboration with Dr. A. Kelly.

To round off the afternoon in a provocative manner, J. van Leeuwen gave "A plastics technologist's view of rheology", which he subtitled "Uses and abuses of rheology by engineers". He felt that technologists with chemistry and engineering backgrounds did not really understand the basic principles of rheology. Dr. van Leeuwen also made a plea for more suitable (i.e. less highbrow) textbooks as he thought that the present ones were written by technologists in despair! His arguments were supported with several good visual illustrations and were evidently well received, no doubt providing talking points for the rest of the meeting.

The highlight of the day was of course the Symposium dinner held at the Conference Centre. Although there were no before or after dinner speeches the event was most enjoyable and provided a pleasant change from the technical sessions. After coffee in the lounge the bar continued to provide liquid refreshment to sustain those present until well past midnight. In consequence conversation flowed very freely although the foam-liquid interface on the beer sank lower as the night wore on.

Delegates reassembled bright and early on Friday morning for the third session which was chaired by Professor Schwarzel. Whether it was due to the hardness of the beds or the personal magnetism of the first speaker is difficult to say. However, there was a good attendance

at 08.30 hours to hear Professor Tanner's clear and relaxed presentation of his paper "Die-swell reconsidered: some numerical solutions using a finite element model". Some useful discussion followed during which it was shown that the computer can be an economic alternative to experiments in dealing with die swell in creeping flow.

The meeting then heard an interesting paper on "Heat transfer to non-Newtonian fluids" presented by Professor Wilkinson of the University of Bradford. He showed that the unacceptably low rates of heat transfer in laminar flowing non-Newtonian fluids can be improved by pulsing the flow. A lively discussion ensued but unfortunately had to be curtailed owing to lack of time.

In contrast to the predominantly Dutch contributions on the first day the second day's papers were mainly on United States and United Kingdom work and another American contribution followed. This was a practical paper on "The source of degradation during extrusion of polystyrene" presented by Dr. Porter, who in describing techniques to assess the extent of shear degradation, reminded us that "the idea of rheology is to produce something useful and is not just a means of consuming power".

With this thought in mind the delegates proceeded to consume coffee and biscuits in preparation for the last two papers of the morning. The first of these was by Professor Metzner on "The contrasting behaviour of dilute solutions (as compared to molten polymers) in extensional flow fibre spinning experiments". This was well received and a fair amount of discussion followed. The next was on "The extrusion coating process—a rheological study" by F. N. Cogswell and D. C. F. Couzens. They explained how one can readily optimize a process for a given polymer, but the means of optimizing a polymer for a given process is more difficult—even with the use of a computer!

After the lunch break Mr. Hutton took the chair for the final session and introduced Dr. Yates of Unilever to deliver the paper "The rheology of mixed surfactant systems". The authors are to be commended on the most generous summary of the meeting that no further comment is necessary.

The last Dutch paper was by M. van dem Tempel on "Rheology of fluid interfaces", perhaps a rather uncommon problem, but nevertheless very interesting.

Tea break was taken and a wearying audience gathered for the concluding papers of the symposium. These were "Extensional flow properties of fibres suspended in Newtonian fluids" by Mewis and Metzner and "Flow of polymer melts containing chopped fibres" by Johnson and Lockett.

Thus a very successful and enjoyable meeting came to a close. The organisers and supporting staff must be congratulated on having arranged a varied programme, ideal meeting accommodation and excel-

lent domestic arrangements. Hearing the papers presented in English left one a little unsure about having been abroad, but the alternative would have introduced additional problems and we are grateful to the Dutch and other European delegates for this. It is likely that all present will look back on their stay in "the happy world" with much pleasure.

Summaries of the papers presented have been published in the June 1973 Rheology Abstracts (Vol. 16, No. 2).

RECENT PUBLICATIONS

Plastics Institute publishes its second Programmed Learning Text Principles of Plastics Extrusion

By J. A. Brydson and D. G. Peacock

A greater volume of plastics materials are extruded than are subjected to any other processing operation. The process is used not only for making end-products but also as an intermediate operation, for example in compounding plastics and in the manufacture of sheet for vacuum forming. Many modern injection moulding machines also operate by an extrusion-type mechanism. It is in fact the case that at some time most of the thermoplastics material that is produced each year is subjected to an extrusion process.

Many personnel engaged in the plastics industry come into contact with extrusion and it is of advantage to them to be aware of the elements of the process. It is the function of this teaching programme to put over such basic elements and although complete in itself it could provide a stepping stone to more extrusion texts on this subject.

Contents: Introduction. How to work through the programme. 1 The nature of plastics. 2 The basic single-screw extruder. 3 Principles of die design. 4 Material characteristics and common extrusion problems. 5 The complete extrusion process. 6 Multi-screw extruders. 7 Miscellaneous uses of extruders. Answers to criterion tests.

Specification: 5½ in. x 9 in., 108 pages, 46 illustrations. Publication date June 1973. Price £2.00.

Enquiries on both this book and its companion volume "Elements of injection moulding", price £1.00, should be addressed to The Plastics Institute, 11 Hobart Place, London, SW1W 0HL (telephone 01-245 9555).

Multiple Transitions in Semi-Crystalline Polymers

A new Plastics Institute publication

This publication is based upon the seventh Swinburne Award address "Why is polyethylene so tough?", given by Dr. R. F. Boyer at the Royal Institution in London on November 30th, 1972.

The publication is devoted almost exclusively to semi-crystalline polymers with special emphasis on the double glass transition; on relationships between different transitions and how these depend on chemical structure; on the use of thermal expansion quantities for characterizing the various transitions; and on the use of homologous series for estimating the "T_g" of polyethylene. The study arose from an inquiry into the glass temperature of polyethylene. In addition, comments are made on the remarkable low-temperature toughness of polyethylene and its possible relationship to both glassy and crystalline transitions lying below room temperature.

Copies of this 24-page publication are now available price 50p each, from the Plastics Institute.

A Review of Recent Publications on Polymer Melt Rheology

A new Plastics Institute information leaflet prepared by L. W. Turner (Yarsley Research Laboratories Ltd.)

A great deal of polymer processing involves large-scale deformations of melts, and such shape transformations have been and continue to be the subjects of intensive investigation.

This literature review is intended to cover recent (i.e. after about 1969) publications in this general area. Eighty-nine references are detailed and reviewed; the material covers introductory texts for those who are perhaps not too familiar with the subject and moves on to more advanced material of considerable interest to those with more academic learnings.

Copies of the leaflet are available price 10p from the Plastics Institute.

THE SOCIETY OF RHEOLOGY

**Annual Meeting, October 28th–31st, 1973, Sheraton-Mount Royal
Hotel, Montreal, Quebec, Canada**

The Macromolecular Science Division of the Chemical Institute of Canada will play the role of host to the 1973 annual meeting of the Society of Rheology in Montreal. This will be the first meeting of the society to be held outside the United States. The honorary host will be Dr. Stan Mason, who is associated with McGill University and the Pulp and Paper Research Institute of Canada and who is a holder of the society's highest award, the Bingham Medal.

There will be a reception for those attending the meeting at the McGill Faculty Club, 3450 McTavish Street, on Sunday evening, October 28th. The Bingham Award Banquet will be held at the hotel on Tuesday evening, October 30th, and on Wednesday evening arrangements will be made for those attending the meeting to dine out

in small groups at one of the charming restaurants of the old quarter of Montreal.

Citizens or permanent residents of the U.S. do not need passports or visas to enter Canada, but immigration officials occasionally request some evidence of U.S. citizenship, so it is suggested you carry something like a birth, baptismal or voter's certificate. Visitors to Canada from countries other than the U.S. must have valid passports. U.S. residents may take up to \$100 worth of merchandise back home if they have been in Canada over 48 hours. Airlines serving Montreal include AER Lingus, Aeroflot, Air Canada, Air France, Alitalia, Allegheny, B.O.A.C., C.P., Delta, Eastern, E.P.A., K.L.M., Lufthansa, Nordair and Quebecair.

The chairman of the local organizing committee is Dr. H. P. Schreiber, c/o Dept. of Chemistry, McGill University, P.O. Box 6070, Montreal 101, Quebec.

Programme Committee

B. D. Coleman, Mellon Institute, Carnegie-Mellon University, Pittsburgh, Pa. 15213.

J. M. Dealy, Department of Chemical Engineering, McGill University, P.O. Box 6070, Montreal 101, Quebec, Canada.

R. F. Landel, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, Calif. 91103.

L. J. Zapas (Committee Chairman), Polymers Division, National Bureau of Standards, Washington, D.C. 20234.

Invited Speakers

Prof. Coleman is organizing a symposium on stability problems. Additional invited speakers will include:

Dr. Richard Stein: "Mechanical Properties of Crystalline Polymers".

Dr. D. R. Axelrad: "Micromechanics in Rheology".

FUNDAMENTALS OF DESIGN IN PLASTICS

Engineering Design

A five-day residential course to be held at Cranfield Institute of Technology, Bedford, from September 24th-28th, 1973. The course fee will be £55.00.

The objective of this course is to enable the student to identify the principal parameters defining mechanical load bearing design problems, to select relevant design data and to make the commonly encountered engineering calculations. He should be able to make an appropriate selection of materials and manufacturing processes and to define

a structural design bearing in mind the economic constraints imposed by practical production.

Full details from Dr. M. W. Darlington, Department of Materials, Cranfield Institute of Technology, Cranfield, Bedford.

Industrial Design

A five-day course to be held at the Royal College of Art, London, from December 31st, 1973–January 4th, 1974. The course fee will be £35.00.

The purpose of the course is to give the members attending an appreciation of the disciplines associated with industrial design; special emphasis will be placed on industrial design relative to the plastics industry.

The course content will be divided into lectures, factory visits and case histories by designers working in plastics. Lectures will be largely given by members of the Department of Design Research and by staff of the School of Industrial Design.

Full details from Mr. N. Chapman, School of Industrial Design, Royal College of Art, Kensington Gore, London, SW7 2EU.

Economics, Marketing and Management

A 4½ day course to be held at Cranfield Institute of Technology, Bedford, probably in March 1974. The course fee will be announced later.

The purpose of this course is to enable the student to develop an appreciation for theories of economics, marketing and management in relation to the manufacture of plastics products with special reference to the essential and systematic interconnections which can be built up between these and the design with engineering disciplines.

Details from The Plastics Institute, 11 Hobart Place, London, SW1W 0HL.

CONFERENCE ON THE CONSERVATION OF MATERIALS

Harwell, March 26th and 27th, 1974

The conference has been arranged by Harwell and the Institution of Chemical Engineers in association with the British National Committee on Materials.

Much of industry depends on a continual supply of engineering materials. (A "material" in this context is any substance from which a useful article or structure can be fabricated, and therefore embraces plastics, ferrous and non-ferrous metals, bricks, timber, etc.) For various reasons the natural resources from which these materials are

made are being consumed at ever increasing rates. The view is therefore gaining ground that we must select and use engineering materials much more wisely than hitherto. Such a policy of materials conservation might include measures such as widening the resource base, more recycling of scrap materials, greater economy of materials usage in the design of articles, increasing the life of articles by improved design, substituting existing materials with different materials based on more abundant resources.

At the suggestion of the British National Committee on Materials this important subject will be discussed at a two-day conference on "The Conservation of Materials". The meeting, which is being jointly sponsored by the Harwell Laboratory of the U.K.A.E.A., and the Institution of Chemical Engineers, will be held at A.E.R.E., Harwell, on March 26th and 27th, 1974. A small number of "key-note" papers will be presented by invited speakers. Other persons wishing to present papers are invited to submit the Title and an Extended Abstract (about 250 words) by September 29th, 1973. Prospective authors are asked to note that although the subject of the conference is but one facet of the global problem of natural resources conservation, their papers should deal primarily with engineering materials and the implications for U.K. industry.

Further details of the conference will be announced in due course. If you wish to submit a paper or be placed on the mailing list for further information, please write to Mr. C. J. A. Preuveneers, Conference Secretary, Education Centre, B.455, A.E.R.E. Harwell, Didcot, Berks. OX11 0QJ. Tel. No. Abingdon 4141, ext. 3106.

Scientific enquiries to Dr. J. B. Morris, Process Technology Division, B.353, A.E.R.E. Harwell, Didcot, Berks. OX11 0RA. Tel. No. Abingdon 4141, ext. 4256.

RECENT ELECTIONS

The following applications for membership have been received and approved:—

Miss B. S. Barratt,
Applied Mathematics Department,
University College of Wales,
Aberystwyth.

Mr. T. H. Farr,
A.P.C.M.,
Greenhithe,
Kent.

Mr. D. C. Tountney,
Applied Mathematics Department,
University College of Wales,
Aberystwyth.

Dr. S. Fewster,
Department of Electrical
Engineering,
University of Glasgow.

DIARY

1973

6-10 August. International Conference on Medical and Biological Engineering. Dresden, German Democratic Republic.

10-14 September. I.U.P.A.C. International Symposium on Macromolecules. Aberdeen.

18-21 September. B.S.R. Autumn Meeting, East Anglia University, Norwich.

24-28 September. Engineering Design. Cranfield Institute of Technology, Bedford.

28-31 October. Society of Rheology. Annual Meeting, Montreal.

31 December-4 January. Industrial Design. Royal College of Art, London.

UNIVERSITY OF SHEFFIELD

Department of Building Science

Applications are invited for Research Studentships leading to a master's degree or a Ph.D. for work on the rheology of cement based materials. Present topics include rheology of Portland cement pastes, workability of fresh concrete, flow properties of grouting materials.

In addition to the scientific interest, these investigations all have implications of practical importance and possible opportunities for work in a major industry.

Candidates should hold, or expect to obtain, a good honours degree in chemistry, physics or materials science.

Further information may be obtained from Dr. G. H. Tattersall, Department of Building Science, University of Sheffield, Arts Tower, Sheffield S10 2TN.