Plastics pipes

1985

6th International Conference

International conference
PLASTICS PIPES VI
26-28 March 1985
(Tuesday-Thursday)

at the University of York

Organized for the PRI Conference Activities Committee by the following:

M J Littlewood (Chairman) (Consultant)
W J Allwood (BP Chemicals)
G H Burke (Consultant)
J A Denning (Stewarts & Lloyds Plastics)
L Ewing (British Gas Corporation)
J B Press (Wavin Building Products)
J N Ratcliffe (PRI Secretary-General)
R E Stephenson (ICI Mond Division)
R C Stokes (Water Research Council Engineering Centre)

Plastics Pipes V was held in York from 8-10 September 1982

THE PLASTICS AND RUBBER INSTITUTE
11 Hobart Place
London SWIW OHL

Telephone 01-245 9555, telex 912881 CWUKTX-G, cables PLARUBINST LONDON SWI

VENUE

The conference will be held at the University of York, Heslington, York YO1 5DD, with the sessions and exhibition being located in the Central Hall (see map).

TRAVEL

Rail - fast Intercity links from London (Kings Cross) and Edinburgh (see note below re coach meeting train)
- direct links from Leeds/Bradford and Newcastle airports
- direct links from Hull and Immingham car ferries

Air - international flights from London (Heathrow), Edinburgh, Leeds/Bradford and Newcastle airports and then linking flights between the major UK airports and Leeds/Bradford airport

Sea - car ferries from Scandinavia and Holland to Hull and Immingham

Once in the vicinity of York you may reach the University as follows:

By bus There are three bus routes from York to Heslington: Nr 5 (from Acomb) via the railway station, Melrosegate and University Road; Nr 19 (from Clifton) via St Leonard's (near King's Manor), Rougier Street, Hull Road and Windmill Lane; and Nr 4B (from the railway station) via Rougier Street, Fulford Road and Heslington Lane.

By car Visitors approaching York from the A64 should turn off at one of the exits marked University, in order to avoid the city centre. Subsequent turns are also signposted. Visitors coming from other directions should take either Fulford Road (A19) and turn at the sign marked University along Heslington Lane; or Lawrence Street (A1079) and turn right at the first traffic lights into Green Dykes Lane, whose extension is University Road.

By taxi Station taxis (telephone 0904 (York) 23332)
Fleetway taxis (York) Ltd (telephone 53344, 53644 or 24998)

A coach will meet those travelling on the 1500 train from King's Cross Station, London, arriving York at 1710 on the Monday evening, and on Thursday a coach will leave the Chemistry Laboratory car park opposite Derwent College at 1340 to take delegates to the station to catch the 1416 train to King's Cross arriving 1622.

Car parking excellent car parking facilities are adjacent to the colleges. Luggage may be unloaded at college entrances but cars must then be parked in the large car parks. They may not be parked in the college forecourts.

ACCOMMODATION (residential delegates only)

Rooms Single room accommodation (each with own washbasin and 250v shaving point) and breakfast have been reserved, if requested, in VANBRUGH COLLEGE on the university campus for the nights of Monday, Tuesday and Wednesday 25, 26 and 27 March, or as otherwise stated in the separate note enclosed with this book.

Delegates should become acquainted with the fire emergency procedures applicable to the accommodation they will occupy. Details are shown on noticeboards in colleges and in study-bedrooms.

On arrival please report to the porter's lodge of Vanbrugh College to which you have been allocated, to collect your room key.

Departure On the day of departure rooms must be vacated by 0930, so luggage must be packed and stored as directed by the college porter.

College telephones (coin operated) are available and should be used for outgoing calls. Overseas calls should be made via the porter at Vanbrugh and Derwent Colleges (a supply of 50p coins will be necessary). In case of emergenc only the following telephone number (the porter's lodge at Vanbrugh College) may be used: 0904 (York) 59861 x 5730.

Normally, messages should be directed to the conference desk: 0904 (York) 410570

Services

a Linen, soap and towels are provided; a shoe-cleaning service is not available, and there is no early morning call system.

b Facilities are available for making tea and coffee in pantries on each floor adjacent to the residential accommodation, and fresh supplies are available daily.

c Valuables can be deposited in college safes, and room keys may be obtained from the porter's lodge.

d Porters are on duty in the college lodges for 24 hours and can assist with luggage, provide stamps, University postcards and change for coin-box telephones, and provide general information and help.

e There are slot machines for cigarettes etc in each college.

HESLINGTON VILLAGE

In the village there is a post office where GIRO cheques may be cashed, a general store, newsagent, greengrocer and branches of the following banks:

Barclays, Lloyds, Midland, National Westminster.

REGISTRATION

The conference registration desk will be open in the concourse of the Central Hall at the following times, and delegates are asked to call here to collect their badge and list of participants:

Monday	1700-1900 2030-2130
Tuesday	0815-1730 (closed for lunch)
Wednesday	0830-1700 (closed for lunch)
Thursday	0830-1230

The telephone number of the conference desk is 0904 (York) 410570

The telephone number of the call box in the Central Hall is 0904 (York) 410468.

MEALS, REFRESHMENTS AND BAR ARRANGEMENTS

Breakfast (residents only) from 0800 to 0900 in Vanbrugh College.

Coffee and tea in the downstairs foyer of the Central Hall at the times indicated in the program. Neither food nor drink may be taken in the main conference theatre at any time.

Lunch for all delegates will be in Vanbrugh College between 1230 and 1400.

ALL DELEGATES MUST WEAR THEIR CONFERENCE BADGES AT MEALTIMES IN ORDER THAT TICKETS MAY BE DISPENSED WITH

Supper on Monday 25 March (for those booked for this on the registration form) will be from 1830 to 2000 in Vanbrugh College.

Dinner The organizing committee believes from previous experience that delegates would welcome the opportunity of a free evening in York on the Tuesday. Therefore there will be no evening meal in Vanbrugh College on that day. For the few who might wish to stay on the campus a meal will be provided in Godricke College but this will be available only by ticket obtainable from the registration desk up until 1100 on Tuesday.

On Wednesday evening the conference dinner will take place in Vanbrugh at 1930, with a sherry reception from 1900-1930. The guest of honour will be the entertainer Peter Maloney. Tickets for non-delegates may be purchased at £19.55 (£17 + £2.55 VAT) if advance notice is given.

Bars will be open at the college as follows:

1200-1400
1800-2330 on Monday and Wednesday
1800-2230 on Tuesday (this will be dependent on the number of delegates staying on the campus and not going into York)

PROGRAM OF PAPERS

Timetable This is set out at the end of these notes.

Smoking Delegates may smoke in the lower foyer of the Central Hall but it is not permitted in the auditorium.

Papers The final program differs slightly from that set out in the registration form, having been augmented by Paper 31A and several poster papers.

Speakers are asked not to exceed the time allocated to them on the program, bearing in mind that this should be used for highlighting the important points in their paper. Projection facilities will be available for 35mm slides and overhead projection. All slides should be in boxes clearly marked with the contributor's name. These should be handed to the projectionist before the start of the appropriate session and be collected after they have been shown.

Chairmen are responsible for keeping authors and discussion contributors to the correct timekeeping.

PUBLICATION OF PROCEEDINGS

It is hoped to prepare a general report on the conference for publication in a future issue of Plastics & Rubber International. The PRI claims the copyright for all the papers, and they must not be reproduced in part or in whole without written permission having first been obtained. All papers will be considered for publication in the Institute's quarterly 'Plastics and Rubber Processing and Applications'.

The texts in this booklet are compiled chiefly for the convenience of those attending the meeting. They have not yet been refereed: the length, form and content may not be appropriate for journal publication. The material contained in these papers may subsequently be published as a substantive publication elsewhere.

EXHIBITION

The exhibition will be located in the Central Hall itself, on the upper tiers at the side of the room (the lower and more central seating is for the conference). Any heavy exhibits will be positioned in the downstairs foyer of the hall.

Ample time has been allowed in the refreshment and lunch breaks to view the exhibition and also before and after the daily conference sessions. It will not be possible to view the exhibits at any other times during the day because of the disturbance to the program. The exhibition will be open

during the period of the conference.

CITY OF YORK

The Tourist Information Office can provide information on local places of interest. A city plan and list of places of interest are enclosed, but a more comprehensive guide is on sale at their office (in the De Grey Rooms, St Leonards, York, telephone 21756).

ENQUIRIES

Enquiries prior to the conference should be addressed to J N Ratcliffe at the Plastics and Rubber Institute, 11 Hobart Place, London SWIW OHL (telephone 01-245 9555, telex CWUKTX-G 912881, cables Plarubinst London SW1).

During the conference the reception desk in the Central Hotel foyer will be manned by Institute staff, and delegates may leave messages or seek information there. It is regretted that it will not be possible to contact delegates other than by showing their names on the message board.

The desk will also have available, for perusal or purchase, a range of Institute publications.

THE PRI

The Plastics and Rubber Institute - an amalgamation of the Institution of the Rubber Industry, founded in 1921, and the Plastics Institute, founded in 1931 - is the oldest and largest international professional society in the world devoted exclusively to providing a service for personnel employed in the plastics and rubber and allied industries.

Over 11,000 members, of whom about half are resident overseas.

The PRI's membership qualifications are internationally recognized as the leading qualifications in the fields of polymer science and technology. Examinations for the higher grades of membership are conducted at various centres throughout the world and are open to members who have completed approved courses of study.

A range of over 80 books, pamphlets and study guides are available at preferential rates to members.

FORTHCOMING EVENTS

1-4 April 1985	Churchill College conference on 'Deformation, yield and fracture of polymers'
15-17 May 1985	Polycons 85: 'Filled and reinforced thermoplastics' and 'Polyethylene film extrusion'
2-4 July 1985	Conference 'Toughening of plastics'
2-3 Sept 1985	London Section conference 'Impact testing and performance of polymeric materials'
5-7 Nov 1985	Materials engineering (ME!) exhibition and conference

PROGRAM AND TIMETABLE

Tuesday 26 March 1985

0900 1 Opening address - a review of the pipe work sponsored by the Polymer Engineering Directorate (PED)
P D R Rice (PED)

SESSION A GENERAL

Chairman Professor D W Saunders (PRI President)

0920 2 The production and properties of die-drawn PE pipe
I M Ward and A Selwood (University of Leeds), B Parsons (QMC) and A Gray (BP Chemicals)

0935 3 Filament wound pipes - machining and finishing
J E Morgan (University of Bristol)

0950 4 Wall-thickness control and on-line inspection of pipes
F H Cooke (Optimum Machinery)

1005 5 Modern extrusion of pipes and profiles: computer controls on extrusion lines
P Fischer and J Wortberg (Battenfeld Extrusionstechnik, F R Germany)

1020 Discussion

1035 Coffee

1105 6 The design and performance of thermoplastic valves
A Dibbo (FIP (UK))

1120 7 Plastics valves in polyethylene natural gas distribution networks
C J Transue (Kerotest Manufacturing Corporation, USA)

1135 8 The monitoring of abrasion resistance of plastics in slurry environments
G P Marshall and D Lowe (Manchester Polytechnic)

1150 9 Weathering of uPVC pipes
R J LeHunt (Humes, Australia)

1205 Discussion

1230 Lunch break

SESSION B TESTING AND PERFORMANCE

Chairman Dr W F Madden (PRI Vice-President)

1415 10 Static calculation of load of buried HDPE pipes with profiled wall and smooth pipe inside
R Koch and R Meldt (Hoechst, F R Germany)

1430 11 Calculation of pipes under multiaxial mechanical strain
G Menges and E Schmachtenberg (IKV, F R Germany)

1445 12 Deflection of uPVC sewer pipes, and a new method for measuring and specifying stiffness of plastics pipes
Nominee of Wavin, Netherlands

1500 Discussion

1515 13 Behaviour of GRP pipes under a variety of load conditions
D H A Rahman, W M Banks and A S Tooth (University of Strathclyde)

1530 14 The influence of bedding and sidefill on the response of uPVC pipes to surface loading
C D F Rogers and S F Brown (University of Nottingham), and G Boyle (British Plastics Federation)

1545 Discussion

1600 Tea

1630 15 In-service durability of uPVC water mains
Sarah Lancashire (Water Research Centre)

1645 16 Relevance and application of fracture toughness measurements for PVC
D R Moore, R Prediger and R C Stephenson (ICI Petrochemicals and Plastics Division)

1700 17 The dynamic fatigue behaviour of uPVC pressure pipe
B W Dukes (IMI)

1715 Discussion

Evening free

Wednesday 27 March 1985

SESSION B TESTING AND PERFORMANCE (cont'd)

Chairman Mr P D R Rice (Director, Polymer Engineering Directorate)

0900 18 New specifications for high toughness in plastics pressure pipes
G P Marshall and M W Birch (Pipeline Consultants)

0915 19 Plane-strain fracture toughness values of ductile plastics pipe materials
D J van Dijk (Plastics and Rubber Research Institute, Netherlands)

0930 20 Fracture arrest conditions in polyethylene (PE) gas pipes
J M Greig (British Gas Corporation)

0945 Discussion

1000 21 Evaluation of the notched ring test as a means of predicting the long-term performance of PE pipes
K Wilson and M Harnett (Stewarts and Lloyds Plastics)

1015 22 Rapid crack propagation in PE pipes studied by modified Robertson tests
M Wolters (Veg-Gasinstituut, Netherlands)

1030 23 Optimizing the resistance of polyethylene to slow crack growth
A Lustiger and R L Markham (Battelle, USA)

1045 Discussion

1100 Coffee

1130 Open forum on Specifications

1230 Lunch break

Chairman Dr A A L Challis CBE (PRI Chairman of Council)

1400 24 Design of bolted flange joints in GRP pipes
E W Godwin, F L Matthews and P F Kilty (Imperial College)

1415 25 The fracture of butt joints in polyethylene pipeline systems
R Parmar and J Bowman (Brunel University)

1430 Discussion

1445 26 Jointing methods for PE casing pipes of district heating systems
F J M Alferink, D G Blom, B Venema and M Wolters (Veg-Gasinstituut, Netherlands)

1500 27 Severn-Trent Water Authority's experience of laying medium density polyethylene pipes for service pipes and water mains
N A Thompson (Severn-Trent Water Authority)

1515 28 Sewer renovation - site experiences and future developments
N L Rice (Rice Associates)

1530 Tea

1600 29 Electrofusion welding prediction and computer-aided design of fittings
G L Pitman (formerly of BP Chemicals, now with BICC Research & Eng)

1615 30 The development of a novel electrofusion system
R G Williams (Stewarts and Lloyds Plastics) and D Ansell (Rutland Plastics)

1630 31A **Characteristics of a good joint with electrofusion fittings**
D Usclat (Gaz de France)

1645 31B **PE jointing techniques**
L Maine and T G Stafford (British Gas)

1700 Discussion

1900 for 1930 Sherry reception

1930 Conference dinner. Guest of honour Peter Maloney

Thursday 28 March 1985

SESSION D APPLICATIONS

Chairman Mr M J Littlewood (Chairman of the Organizing Committee)

0900 32 Trends in plastics pipe usage
J S Murphy (Consultant Editor Plastics & Rubber International)

0920 33 Use and specification of GRP pipes in Abu Dhabi area
C W M McDowell (McDowell CoPartnership)

0935 34 The growing interest in high pressure, large-diameter GRP pipelines
F H Hooning (Wavin, Netherlands)

0950 35 Unique usage of high-density polyethylene piping systems
B J Sanders (Phillips Driscopipe, USA)

1005 Discussion

1020 Coffee

POSTER PAPERS

A REVIEW OF THE PIPE WORK SPONSORED BY THE POLYMER ENGINEERING DIRECTORATE (PED)

P. D. R. Rice
Polymer Engineering Director - SERC.

SUMMARY

The Polymer Engineering Directorate of SERC has played a major part in sponsoring research and development of plastics pressure pipe systems over the past eight years. Since its inception PED has been involved with both thermoplastic and GRP pipe programmes and to date has invested approx. £2 million of Government finance in Research and Development.

The programmes sponsored have covered processing, properties and design aspects and have all been collaborative ventures with academic groups and industrial partners.

1. THE POLYMER ENGINEERING DIRECTORATE

During the early years of the 1970's it was recognised that the expansion of the use of polymers in many different engineering application warranted the development of a new discipline of Polymer Engineering. At that time there was very little co-ordinated activity between research groups in academy and industry and for the most part, University research was heavily concentrated on thermoplastics processing activities in the Fluid Mechanics/Heat Transfer Sections of Engineering Departments and on Polymer Physics studies - largely in loose co-operation with major resin suppliers.

Funding for these research activities was made to the Universities via the Science Research Council and there was no requirement for research groups to be engaged in other than 'blue-sky' activities.

In a major attempt to change not only the direction of research activities but also the attitudes of both academics and industrialists towards joint-venture research programmes, the SRC set up the Polymer Engineering Directorate (PED) to co-ordinate SRC funding of research and education in Polymer Engineering.

The initial concept was to form an "Invisible University" made up of a widespread group of academics in both Engineering and Polymer Physics/Technology Departments of different Universities and Polytechnics. The generation and co-ordination of this community is a primary function of PED, which also provide the direct link with Industry to ensure that the activities which are sponsored are of more immediate, direct relevance, than the general polymer research projects funded by conventional SERC Committees.

There are three broad groupings of PED sponsored work, viz:

i) The generation of projects concerned with aspects of Engineering of Polymers. Largely, this is research in the engineering of different techniques for converting polymers resins/granules into artefacts.

ii) The development of research aimed at promoting excellence in the field of Engineering with Polymers, e.g. Applications of fracture mechanics to design, studies of material structure/property relationships, etc.

iii) The promotion of better education and teaching on Polymer Engineering topics in University/ Polytechnic Engineering & Material Departments.

In all these areas, the use of polymers for pressure pipe systems has been a significant area of reseach activity of the PED over the last 8 years.

2. PLASTICS PIPE RESEARCH VIA PED

Introduction

The Plastics Pipe Industry in the U.K. is a significant part of the Plastics Industry as a whole. Thermoplastic Pipes are produced from uPVC, Low, Medium and High Density PE, PP and ABS and composite pipes are made using centrifugal casting, 'contact moulding' and filament wound techniques. Although most pipe is used within the Water and Gas Supply Industries, there is a large export business - particularly with ABS, the MDPE gas pipe systems and GRP sewer/effluent disposal pipes.

Because almost all the raw materials used are themselves manufactured in the U.K., there is a closed-loop situation which makes research funding of projects more attractive.

Also, there is a wide range of production techniques involved in pipe production, which is of relevance in attracting Engineering Departments to become involved with research since it broadens the scope of interest for both academic staff and students alike. Even though the U.K. has lost a large part of the plastics processing equipment market to other nations, there is still great scope for utilisation of processing expertise to improve manufacturing technology in pipe production plants.

Since pipe is a simple geometry in comparison with the highly complex articles produced in plastics for other applications and since the service condition of pressure loadings and soil/traffic deformation can often be defined in straightforward engineering terms, the operation of a pressure pipe system provides an excellent example both for teaching purposes and for testing models of behaviour predicted by laboratory property studies. Pipes need to operate over a wide regime of temperatures and environmental conditions and the choice of suitable materials depends on an understanding of deformation and failure processes - areas of some considerable expertise within both academy and industry in the U.K.

The feedback on service performance and the specification of clear design criteria in the Gas Industry has been made simple via the Engineering Research Station of BGC, and latterly the Water Research Centre is striving to provide similar crieteria of performance for the Water/Sewerage Industries.

With a co-ordinated approach from the end-users of pipes, it is simpler to define a strategy to provide funding for a more relevant research programme. Indeed, it is significant that during the lifetime of the PED, there has been a considerable change in the format of the academic/industry partner group due to changes which have occurred in the Pipe Industry as a whole.

In the early years of PED, the emphasis of industrial collaboration was via contacts with the raw material suppliers. In the early/mid 70's, research on pipes was largely carried out by the large material suppliers. The demands of ERS (and latterly WRC) that the pipe producers should take the lead in demonstrating that pipes have adequate properties for the service envisagedvia extensive, phased 'approvals' procedures involving much sophisticated testing, has lead to a highly expert prcoessing industry who have been highly responsive to the collaborative research activities promoted by PED.

It is interesting to note that although numerous companies manufacturing both thermoplastics and composite pipes have ceased trading since 1976, those involved with PED projects have survived and in most cases are prospering.

The range of research activities sponsored by joint SERC /Industry financing of research projects in Universities and Polytechnics is summarised in Table 1. It can be broadly divided into three spheres, viz:

2.1 Processing Research

In the last eight years, PED has generated 14 different projects connected with the promotion of research into extrusion and injection moulding processes of direct relevance to producers of uPVC and MDPE pipes/systems. Although much of this work has been on screw design and mixing processes, largely at Brunel, Cranfield and Bradford Universities, there has been considerable effort devoted to novel techniques of pipe/fitting production at UMIST and Brunel. In particular, rotating die technology has been transferred to pipe applications via research at UMIST into means of generating preferred orientation of fibres in glass reinforced thermoplastic pipe and Brunel have examined new techniques of melt filtration and flow moulding for the production of thick sectionsappropriate to fittings design. Differential cooling across thick sections can give rise to significant stresses and SERC has sponsored work to assess these. Complementing this work, the complex problem of heat transfer during the cooling of thick walled PE pipes has been examined by Bradford University using techniques and analyses developed from studies of blow mouldings.

Altogether, PED has directly provided of £1/2 million of Government finance for this processing research - and pipe processors have contributed both in cash and 'kind' on most of the programmes.

2.2 Physical Property Research

Although Processing Research has been overwhelmingly concerned with thermoplastics pipes, the research on measurement and analysis of physical properties relevant to service performance of pipes have also included work on GRP composites to a significant degree. In particular, work has been sponsored at Nottingham on the fatigue of filament wound pressure vessels and Liverpool, Bath and Surrey Universities have all carried out intensive programmes of work on Environmental Stress Cracking phenomena in composites - of great relevance to sewerage pipes which are largely made from GRP by U.K. companies in Middle East 'operations'. As a consequence of these studies and other academic programmes in the U.K., the mechanism of ESC in GRP is now clearly defined and the role of resin and glass components is understood.

The research on properties of thermoplastics systems has been overwhelmingly devoted towards understanding failure mechanisms. From the outset of PED, there has been major effort, sponsored at Imperial College, Brunel and Manchester Polytechnic, into relating service failure problems with uPVC pipes (and certain PE welded joints) to polymer structure and processing conditions. The effects of both fatigue loading and long term static loading have been assessed and the collective work has resulted in changes to the British Standard for uPVC and to specification development for MDPE.

In present studies, being sponsored at Imperial College, the difficult problem of establishing parameters controlling unstable failure in High Toughness MDPE is being considered.

These programmes of work have been strongly supported by all sections of the Plastics Industry and in latter years by the Water and Gas Industries. Approximately £1 million of PED money has been channelled into Universities and Polytechnics in this area, with a further 25% industrial contribution.

2.3 Design of Pipe Systems

From the outset of PED, it was recognised that there was a demand to have better design codes of practice for GRP pipe systems used for chemical plants etc. The GRP pipe industry supplying to this market was not supported by any fundamental research effort from elsewhere and had limited resources to carry out the required work in-house. A large project led by the Civil Engineering Department at UMIST and including RAPRA and NEL has co-operated with pipe producers to establish design criteria for fabricated bends, tees, elbows, etc., for this particularly demanding duty. Other work at Imperial College has examined stresses in in flanged pipe connections in GRP.

Thermoplastic design work has been more widely spread with projects covering diffusion of hostile liquids, system design and transient pressure measurements in MDPE Pipes.

Altogether, PED has funded research to a value of £1/2 million on design aspects over its period of office.

2.4 D.O.I. Funding

Besides dealing with the dispensation of SERC monies for applied research in Polymer Engineering, the PED has also acted to co-ordinate research funding in Polymer Topics for the Department of Industry.

The Plastics Pipe Industry has benefitted substantially from this activity particularly on the assessment of the performance of blue MDPE pipe systems in the Water Industry. A large project has been established to monitor the performance of MDPE in large scale field trials with Yorkshire, Severn-Trent and North West Water Authorities. The performance of uPVC is also being followed. This programme is backed-up by laboratory experimental work at Brunel University and Manchester Polytechnic who are evaluating pipe behaviour under simulated field conditions.

The Water Research Centre are in charge of this project and they also work with ERS at British Gas in a programme on attempts to produce artificially induced unstable failure in pipes. The programme is backed by B. P. Chemicals and Pipe Producers.

On such projects, the PED advises the DOI on H. M. Government expenditure and is involved in the strategic sense rather than in month to month detailed co-ordination.

3. BASIS FOR SUPPORT OF PROJECTS

In examining the list of projects on pipes which the PED has supported it is of interest to note that the emphasis of the research activity has altered considerably.

The early projects - particularly on uPVC - were largely connected with test programmes to generate information which would explain the uneven service performance of some types of pipe. This problem-solving activity continued and was developed to change Standards and develop design codes for fatigue, etc. As time has gone by, the backlog of 'problems' has diminished and the overall research direction has changed towards work on new materials, new types of production, simulation of service for new applications etc. i.e. The research has moved to anticipate 'future' developments rather than be concerned with retrospective investi-

gatory work. As the processing industry has seen that academic research groups are committed to the promotion and survival of a viable, high technology plastic pipe industry, co-operation and collaboration has improved.

The division of the projects is seen to be a fair reflection of the usage of pipe within the U.K. Thermoplastics pipes research has received the greatest slice of finance and the programmes have tended to be collaborative ventures with raw material and pipe suppliers and latterly with Specifying Authorities representing the end-user. The materials of primary interest have been uPVC and MDPE purely because these are the materials used for the overwhelming majority of plastics pipes currently being used in the U.K. Although work on ABS and PP has received some minor funding, there has been no demand for further research from either academy or industry.

Whilst there is much interest on the Continent for use of cross-linked polyethylene and polybutylene for district heating pipe systems, there are no projected plans for the widespread use of district heating in the U.K. However, since at least two pipe companies have developed ventures into cross-linked polymers, two projects have recently been undertaken at Manchester and Brunel to ensure that a research base is established with these potentially important materials.

With GRP pipe systems, almost all the research supported by PED has been design oriented. Again, there has been no groundswell of opinion from pipe producers to expand research since very little pressure pipe in GRP is used within the U.K. Water Industry. The use of GRP pipework for chemical plant applications has also diminished following the general recession of new plant construction in the Chemical Industry as a whole. This situation may well change in the future however, as conventional materials such as ductile iron and asbestos cement are used less frequently because of corrosion and 'safety' problems. GRP pipe would be an attractive alternative material for water and sewerage transmission and if so, there is expertise in academy which could be used to support any increase in usage of GRP.

4. CONCLUSION

During the past eight years, PED has committed £2 million of SERC finance into plastics pipe and pipe-related programmes.

The interest in collaborative research projects has been maintained over this period both by academy and industry. The industrial interest now has an even balance of material suppliers, pipe producers and end users. The academic balance is also spread between Universities and Polytechnics and it is encouraging to note that groups who were involved with early pipe programmes are continuing to conduct on-going projects on pipe performance etc.

It is believed that the overall investment of SERC finance into the pipe industry has produced effective results. The companies who have collaborated have been assissted in their effort to maintain their position as major pipe suppliers to the Gas/Water/Industrial markets. It is hoped that in spite of the general recessionary trend, the Plastics Pipe Industry has a sound technical base to allow for future expansion.

TABLE 1 - Spread of PED Finance for Pipe Projects 1976 - 1985.

ACTIVITY	NO. GRANTS AWARDED	GRANT VALUES
Injection Moulding	2	£151,000
Extrusion	9	£306,000
Novel Processing Techniques	3	£54,000
Fatigue Studies (GRP, PVC, PE)	4	£120,000
Fracture Studies (PVC, PE)	8	£374,000
Structure/Property Studies	6	£191,000
Unstable Failure/Impact	2	£183,000
ESC of GRP	4	£113,000
Design of GRP	6	£350,000
Design of PE	6	£142,000

THE PRODUCTION AND PROPERTIES OF DIE-DRAWN PE PIPE

I.M. Ward*, A. Selwood*, B. Parsons+ and A. Gray[1]

The process of die-drawing has been investigated as a means of producing oriented polyethylene pipe. Two materials, one homopolymer and one copolymer, have been successfully drawn into pipe. When compared with isotropic pipes the oriented products exhibit enhanced mechanical and physical properties and produce a novel pipe performance.

INTRODUCTION

There has in recent years been substantial research into the preparation and characterisation of polymers containing high degrees of molecular orientation. One of the prime reasons for this level of activity is the enhancement of physical properties beyond those of isotropic materials. Research work at the Department of Physics, Leeds University has been at the forefront in this area, notably on high density polyethylene (HDPE). A great deal of the pioneer work was performed on conventional tensile testing machines to produce oriented strands (1). However, more recently other solid phase drawing techniques have been studied which enable products to be fabricated with much larger overall dimensions (2-4).

This paper considers aspects of manufacturing pipes of oriented HDPE by the technique of die-drawing (3). The pipes have also been assessed regarding some of their physical properties.

EXPERIMENTAL PROGRAMME

Materials

Information relating to two materials will be reported. The first, a homopolymer of density 960 kg/m^3 and melt index 0.6 gm/10 min, was chosen due to previous experience of the material on a die-drawing apparatus of smaller scale. The second, a copolymer of density 947 kg/m^3 and melt index 0.2 gm/10 min, was studied because of an anticipated improvement in mechanical properties.

Billet Manufacture

In order to proceed with the work the first essential is the provision of starting billets which possess good dimensional tolerances and are free from voids. Cylindrical billets were manufactured by melt extrusion using a 2.5 inch single screw machine. The extruder was equipped with a 63 mm O.D. die and a 20 mm mandrel. The outer diameter was controlled by vacuum sizing. Alteration of extrusion conditions and haul-off speed were used to give final dimensions of 63 mm O.D. and 25 mm I.D.

*Department of Physics, Leeds University, +Department of Mechanical Engineering, Queen Mary College, [1]Research and Development Department, BP Chemicals Limited.