THE PLASTICS AND RUBBER INSTITUTE
11 Hobart Place London SW1W 0HL

INTERNATIONAL CONFERENCE

# PVC Processing II

The Metropole Hotel – Brighton

26–28 April 1983

# PVC PROCESSING II CONFERENCE – 26, 27 and 28 APRIL 1983

## GENERAL INFORMATION

### Purpose

The aim of the conference is to bring together an international gathering of experts from every aspect of PVC processing to discuss the latest advances, research topics and future developments.

### Sponsor

The conference is being organised by the Plastics and Rubber Institute.

The organising sub-committee comprises:

*Chairman:* P Sime (ICI)

*Members:* P Baker (Commercial Plastics)
J B Press (Wavin Plastics)
Dr D A Tester (ICI)
Dr R R Smith (Lancaster University)
K C Weddle (Uniplex Machinery Sales – Battenfeld)

*Secretary:* G W Stockdale (Plastics and Rubber Institute)

### Venue

The conference will be held at the Metropole Hotel, Kings Road, Brighton, Sussex BN1 2FU (Telephone: 0273-775432, Telex 877245). Special accommodation rates are available to delegates who should book direct with the hotel. There are frequent trains from London (Victoria) and there are adequate car parking facilities adjacent to the hotel.

### Name badge and list of delegates

The list of delegates and name badges will be available for collection from the conference reception desk during registration, 1700–1830 and 2130–2230 on Monday 25 April and 0800–0930 on Tuesday 26 April. Delegates are asked to wear their name badges throughout the conference. Speakers, chairmen and committee members' badges will be in RED and delegates in BLUE.

### Publication of proceedings

A general report on the conference will be prepared for publication in a future edition of the PRI members' journal 'Plastics and Rubber International' in which certain of the papers may also be reproduced. Consideration will also be given to including some papers in the Institute's research and development quarterly 'Plastics and Rubber Processing and Applications'. The PRI claims copyright of all the papers and none must be reproduced in whole or in part without written permission having first been obtained.

### Discussions

The discussion periods will be an important part of the meeting and the co-operation of all concerned is sought in keeping to the timetable. Delegates are asked to be concise to allow the maximum number to participate.

## THE PLASTICS AND RUBBER INSTITUTE

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 a registered educational charity and the oldest and largest international professional society in the world which is devoted to providing a service for personnel employed in the plastics and rubber, and allied industries.

The Institute's principal aims and objectives are: the development for the public benefit of a professional body comprising members concerned with the art, science and technology of plastics, rubbers and other high polymers in academic, research, commercial and administrative capacities, and the advancement of the standard and methods of education and training at all levels in these fields and related technical and non-technical subjects, including management, economics and finance.

The present membership totals over 11,000 individuals of whom about 5,000 are resident overseas. There are 16 geographical sections in the UK and 11 overseas – Australasia, Belgium, Hong Kong, India, Malaysia, Netherlands, Singapore, South Africa, Sri Lanka, Zimbabwe and General Overseas.

The Institute (a) organizes about 200 meetings each year from headquarters and in the local sections (b) publishes bi-monthly 'Plastics and Rubber International'; a quarterly research journal 'Plastics and Rubber Processing and Applications'; and a range of over 80 books, pamphlets and educational materials (c) is a qualifying body and the grades of membership awarded are: Fellow (FPRI), Member (MPRI), Associate Member (AMPRI), Graduate (GradPRI), Licentiate (LPRI) and Diploma member. MPRI is a degree level qualification.

**Subscription 1982/83**

| | | |
|---|---|---|
| Student | £ 7.00 | General Overseas Section £ 6.00 |
| Ordinary (under 25) | UK £12.00 | General Overseas Section £ 9.00 |
| Ordinary | UK £24.00 | General Overseas Section £18.00 |

## PROGRAMME

### Timetable

This is detailed on pages iv to vii

### Biographical Details

Papers 1–37

**Refreshments and luncheon**

Coffee and tea will be served at the times stated in the programme in the Ambassador and Primrose Rooms. Luncheon will be served in the Winter Garden: hot and cold buffet will be available to allow delegates to circulate informally.

**Conference Dinner**

The conference dinner will be held in the Winter Garden at 2000 on Wednesday 27 April. Pre-dinner drinks will be available at cash bars in the Ambassador and Primrose Rooms, and afterwards until 0030.

**Conference Office**

The conference office will open for registration from 1700–1830 and 2130–2230 on Monday 25 April and from 0800 on Tuesday 26 April. The office will be open during conference hours to assist delegates. A selection of the Institute's publications will be available for perusal and purchase.

**VAT invoice**

All those who have paid the appropriate conference registration fee, and who have requested a VAT invoice, will find the invoice enclosed. Please pass it to your accounts department.

**Enquiries**

Enquiries before the conference should be addressed to G W Stockdale at the Plastics and Rubber Institute, 11 Hobart Place, London SW1W 0HL (telephone 01-245 9555).

## POSTER SESSIONS – Northend Room (adjoining the Clarence Room)

The authors of posters will be available for informal discussion with delegates between 1700 and 1830 on Tuesday 26 April, and 1750 to 1830 on Wednesday 27 April. The posters will remain on display throughout the conference.

P1 ✓ The use of thermally stimulated currents for studying the compatibility of PVC/PMMA blends.
Dr J Vanderschueren (The University of Liege)

P2 ✓ The effects of gelation on the mechanical behaviour of uPVC
Dr J F Jansson and Dr B Terselius (The Royal Institute of Polymer Technology, Stockholm)

P3 New blowing agents for PVC
A Hunter (Fisons)

P4 PVC NBR blends
P Tandon (Goodyear)

P5 ✓ Omya-Hydrocarb 95T – the new filler for rigid PVC
I D Hounsham (Croxton and Garry)

P6 Re-inforcement of flexible PVC with Santo web W Fibre
W Spreutels and Dr J M Campbell (Monsanto Europe SA, Brussels)

P7 An evaluation of the RAPRA CTM cavity transfer mixer for the extrusion of flexible and rigid PVC
Dr M Gale (Rubber and Plastics Research Association)

P8 Thickness profile control on calendered and extruded plastic sheet with a novel, inexpensive system based on a single board computer
M King and J Cameron (Kineron Gauging Systems)

P9 ✓ Compatibility of PVC with other polymers
Dr A Crusos (Institute of macro-molecular chemistry, IASI, Roumania)

P10 Specialty impact modifier for packaging of edible oils and fruit squash
Dr J Mooney (Rohm and Haas, France)

P11 The mechanism of PVC welding
Dr D W Clegg and Dr J Abraham (The University of Sheffield)

## PROGRAMME

Tuesday 26 April 1983

*PLENARY SESSION* – GENERAL AND FUNDAMENTAL – Clarence Room

| | | |
|---|---|---|
| *Chairman:* | | Dr L Mullins (President of the Plastics and Rubber Institute, Director of MRPRA) |
| 0930 | | Chairman's opening remarks. |
| 0940 | 1 | **The commercial future of PVC**<br>W J Prinselaar (General Manager (Commercial) ICI, V and P Division, Brussels) |
| 1010 | | Discussion |
| 1030 | | Coffee |
| 1100 | 2 | **Characterisation of PVC polymers**<br>M Clark (ICI Barry – formerly BP Chemicals) |
| 1130 | 3 | **Fusion characteristics of PVC**<br>Dr G Schoukens (Solvay and Cie SA, Brussels) |
| 1200 | 4 ✓ | **The mechanism of gelation of uPVC during processing**<br>M W Allsopp (ICI Petrochemicals and Plastics Division) |
| 1230 | | Discussion on papers 2, 3 and 4 |
| 1245 | | Lunch |
| *Chairman:* | | J B Press (Wavin Plastics) |
| 1415 | 5 ✓ | **Assessment of fusion in PVC compounds**<br>Dr M Gilbert, D A Hemsley and A Miadonye (The University of Technology, Loughborough) |
| 1445 | 6 | **Some effects of compounding history on the structure and rheology of plasticised PVC**<br>R C Stephenson and Dr M Bottrill (ICI Petrochemicals and Plastics Division) |
| 1515 | 7 | **Toughness in rigid PVC pipe and the mechanism of fracture**<br>Dr F T Murphy and Dr D Walton (Wavin Plastics) |
| 1545 | | Discussion on papers 5, 6 and 7 |
| 1600 | | Tea |
| 1630 | | Forum and brief review of posters |
| 1700–1830 | | Poster session |
| 1900–1945 | | Civic Reception in the Skyline Restaurant at the Brighton Centre. |

Wednesday 27 April 1983

Concurrent specialised sessions in the Clarence Room and Norfolk Room

*EXTRUSION* – Clarence Room

| | | |
|---|---|---|
| *Chairman:* | | K C Weddle (Uniplex Machinery Ltd) |
| 0900 | 8 | **Twin screw extruder and die design**<br>U Scheiblbrandner (Cincinnati Milacron, Austria) |
| 0930 | 9 | **Screw design for wire coating**<br>Dr Buluschek (Maillefer, Switzerland) |
| 1000 | | Discussion on papers 8 and 9 |
| 1015 | | Coffee |
| 1045 | 10 | **Extrusion process control**<br>Dr P Fischer (Battenfeld, FR Germany) |
| 1115 | 11 | **Extrusion of PVC on single and twin screw extruders**<br>Professor Dr G Menges, E Krüger and Dr J Parey (IKV, Aachen) |
| 1145 | 12 | **Orientated PVC pipes**<br>M J Littlewood (IMI Yorkshire Imperial Plastics) |
| 1215 | | Discussion on papers 10, 11 and 12 |
| 1230 | | Lunch |
| 1400 | 13 | **The effect of extrusion conditions on the fusion, structure and properties of rigid PVC**<br>Dr D E Marshall, Dr R P Higgs and O P Obande (The University of Technology, Lougborough) |
| 1430 | 14 | **The role of the ultimate elastic wall stress in predicting PVC pipe performance in practice**<br>H F Schwencke (Shell, Holland) |
| 1500 | | Discussion on papers 13 and 14 |
| 1515 | | Tea |
| 1545 | 15 | **The PVC window frame**<br>Dr R Lyall (Hepworth) |
| 1615 | 16 | **The effects of acrylic process aids and impact modifiers on the processing and physical properties of extruded rigid PVC**<br>Dr J Mooney (Rohm and Haas, France) |
| 1645 | 17 | **Titanium dioxide as a colourant and UV stabilizer in uPVC systems**<br>Dr W J Ferguson and Dr B E Hulme (Tioxide (UK)) |
| 1715 | 18 | **Rigid PVC foam profiles**<br>R Brown (Hollicell) |
| 1735 | | Discussion on papers 15, 16, 17 and 18 |
| 1750 | | Close of session |
| 1750–1830 | | Poster session |
| 1930 for 2000 | | Conference Dinner |

Wednesday 27 April 1983

*CALENDERING, BLOW MOULDING, FORMING AND COATING* – Norfolk Room

| | | |
|---|---|---|
| *Chairman:* | | P Sime (ICI) |
| 0900 | 19 | **Precise manufacturing tolerance for calendered PVC films**<br>E Salo (Oy Wiik and Hoeglund, Finland) |
| 0930 | 20 | **Formulating for glass-clear film and sheet**<br>Dr G Hatzmann and G Muller (BASF, FR Germany) |
| 1000 | | Discussion on papers 19 and 20 |
| 1015 | | Coffee |
| 1045 | 21 | **Printed PVC veneers**<br>P Baker (Commercial Plastics) |
| 1115 | 22 | **Plasticisers for PVC – a review**<br>Dr D L Buszard (Ciba Geigy, UK) |
| 1145 | 23 | **The stabilization of flexible and semi-rigid PVC – a time of change**<br>D J Dunne (Diamond Shamrock) |
| 1215 | | Discussion on papers 21, 22 and 23 |
| 1230 | | Lunch |
| *Chairman:* | | Dr D A Tester (ICI) |
| 1400 | 24 | **High frequency welding**<br>M R Ward and G V Whitaker (Stanelco) |
| 1430 | 25 | **The bi-axial orientation process for the production of PVC bottles**<br>M Weiss and K Whitehead (Bekum, FR Germany) |
| 1500 | | Discussion on papers 24 and 25 |
| 1515 | | Tea |
| 1545 | 26 | **Fire-retardant upholstery foams and coatings**<br>A H Radcliffe (Elson and Robbins) |
| 1615 | 27 | **Developments and innovations in PVC flooring**<br>R Blass (Pegulan AG, FR Germany) |
| 1645 | 28 | **PVC paste polymers from the processor's viewpoint**<br>G Niven (Nairn Coated Products) |
| 1715 | | Discussion on papers 26, 27, and 28 |
| 1730 | | Close of session |
| 1750–1830 | | Poster session |
| 1930 for 2000 | | Conference Dinner |

Thursday 28 April 1983

*CONCURRENT SPECIALISED SESSIONS* in the Norfolk and Clarence Rooms

Followed by a *PLENARY SESSION* in the Clarence Room

### *INJECTION MOULDING* – Norfolk Room

| | | |
|---|---|---|
| *Chairman:* | | P D R Rice (Director, Polymer Engineering Directorate) |
| 0900 | 29 ✓ | **Injection moulding of uPVC powder**<br>V Gardner (Bone Craven) |
| 0930 | 30 | **Process control in PVC moulding**<br>A Ganzeman (Stork Plastics, Holland) |
| 1000 | 31 ✓ | **The design and manufacture of tooling for PVC injection moulding**<br>H Plater (Consultant) |
| 1030 | | Discussion on papers 29, 30 and 31 |
| 1045 | | Coffee |

### *FEEDSTOCK PREPARATION* – Clarence Room

| | | |
|---|---|---|
| *Chairman:* | | Dr D A Tester (ICI) |
| 0900 | 32 | **The economics of a mixing plant**<br>T K Fielder (T K Fielder Ltd) |
| 0930 | 33 ✓ | **Continuous compounding of PVC on the extruder**<br>M Weber (Colortronic Reinhard, FR Germany) |
| 1000 | 34 | **Factors influencing the development of PVC additives**<br>Dr V Oakes (Akzo Chemie, Holland) |
| 1030 | | Discussion on papers 32, 33 and 34 |
| 1045 | | Coffee |

### *FINAL PLENARY SESSION – GENERAL* – Clarence Room

| | | |
|---|---|---|
| *Chairman:* | | Mr P Baker (Commercial Plastics) |
| 1115 | 35 | **Health and safety aspects of PVC processing**<br>H M Clayton (Norsk Hydro Polymers (UK)) |
| 1145 | 36 | **PVC and fire**<br>Dr K T Paul (Rubber and Plastics Research Association) |
| 1215 | 37 | **A philosophy of quality assurance**<br>D A Trebucq (Wavin Plastics) |
| 1245 | | Discussion of papers 35, 36 and 37 |
| 1300 | | Chairman's closing remarks – P Sime (ICI) |
| 1315 | | Lunch |

## THE COMMERCIAL FUTURE OF PVC

by W.J. Primselaar
ICI Europa Limited

### 1. Historical development of PVC.

First produced in early 1930s and developed as a rubber substitute in the 1939-45 World War. Has since grown to become one of the major bulk plastic materials with a world consumption of 11-12 million tonnes.

### 2. Versatility of PVC.

Available in a wide variety of forms varying from fully rigid to highly flexible. Can be formulated glass clear or opaque, and in a full range of colours. Suitable for use in demanding climatic conditions, and available in forms suitable for foodstuffs packaging and medical applications.

### 3. Wide range of end-uses.

Approximately 50% used in building and construction applications such as pipes, roofing sheet, window frames, electric cables, flooring. In addition, wide range of other end-uses eg. bottles, packaging film, gramophone records, wiring for household durables, automobile upholstery, footwear, toys.

### 4. VCM toxicity problem.

Serious threat posed to PVC by the vinyl chloride toxicity problem which was uncovered at the end of 1973. Problem satisfactorily resolved by the industry by means of some important technological advances. Recognition of the fact that PVC as a raw material is of vital importance within the total economy.

### 5. Threat posed by oil price escalation.

Following the initial step change in oil prices at the end of 1973, question mark raised about the competitive position of all plastics raw materials. Nevertheless despite the escalation of oil and energy prices, plastic materials have maintained their competitive position in general, and PVC has been at some advantage over other plastics being only 50% derived from ethylene.

## 6. Current threat posed by overcapacity and unprofitability.

Steep fall in market growth trend since 1973 has resulted in gross overcapacity on PVC and other bulk plastics. This, coupled with increased pressure from imports from outside W. Europe, has caused price weakness and the whole PVC industry has become extremely unprofitable, with all major manufacturers accumulating large losses.

## 7. The way foward.

- Mature phase of product life cycle.
- Reduced long term growth trend.
- Industry rationalisation.
- External pressures from Eastern Europe and Middle East.
- Restoration of industry profitability.

# CHARACTERISATION OF PVC POLYMERS

M Clark *

The characteristics and methods of characterising powder and processing properties of suspension/mass and paste forming polymers will be reviewed. Special emphasis will be placed on the relationships between the fundamental aspects of the resin and its performance in the more directly process related evaluation tests.

The main areas covered will include a brief assessment of the state of the art regarding molecular structure determination and its relevance to PVC thermal stability. The importance of particle morphology will be stressed and a variety of appropriate evaluation techniques described. A wide overview of particle size measuring techniques, including several recent instrumental methods, will be given together with a personal view of their respective merits. The possibility of using shear cell measurements to predict bulk handling characteristics and in the design of silos will be referred to.

The presentation will also outline the wide range of heat stablility testing used in the industry and indicate their relative value.

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* ICI - formerly with BP Chemicals Ltd

# FUSION CHARACTERISTICS OF PVC

G. Schoukens*

Polyvinyl chloride presents a complex supermolecular structure which strongly influences its flow behaviour and physical properties. The so-called "primary particles" are clustered together into agglomerates and subgrains. During processing, PVC can be below its final melting point and the flow processes are then assumed to be particulate. Above a certain temperature, the flow processes are controled by the standard rheological rules for molten polymers. The processing conditions are strongly influenced by the K-value of PVC.

## INTRODUCTION

Although polyvinyl chloride is one of the oldest and most widely used commercial polymers, efforts to understand its flow characteristics, structure and physical properties have only be done effectively in the last decade.

The physical structure of PVC, more than in any other polymer, is crucially important in determining its flow behaviour. Why is flow behaviour so important ? To be commercially useful, a plastic must have suitable flow properties to be extruded or injected. It controls, indirectly, the mechanical properties of the final product.

Polyvinyl chloride forms a complex supermolecular structure where the "primary particles", about one micron diameter, are clustered together into agglomerates and subgrains. During processing, PVC can be below its final melting point or above and the internal structure changes continuously during processing. The final structure obtained is strongly influenced by the used processing conditions. In some cases, after processing, many different size particles have been identified in PVC (1). The nature of these subprimary particles is still a subject of debate.

* SOLVAY & CIE, S.A., Central Laboratory, 310, rue de Ransbeek, 1120 Brussels

## FUSION CHARACTERISTICS OF PVC

The IUPAC Working Party on Structure and Properties of Commercial Polymers undertook recently an extensive study on this subject (2). The goal of these studies was to identify the subprimary structure of PVC and elucidate its role during flow. The conclusion of those studies was that the most likely flow unit in unplasticised PVC is an approximately spherical domain of about 100 nm diameter, undeformable, whereby the connective tissue between the domains appears to be very highly deformable. These internal transformation of the structure of PVC can be followed during the fusion process.

### Processing of PVC

Normally, the internal structure-transformations of PVC are characterised by a starting temperature of fusion and an end temperature. The process of fusion is a dynamic process, so the parameter time is also an important parameter. The temperature range of fusion and the processing-time are two important parameters during the processing of PVC.

The temperature where the structure-transformations of PVC begins is strongly influenced by the polymerisation technique of PVC. This temperature is a function of the formed "primary particles" during the polymerisation and also of the structure of agglomerates and subgrains in the PVC. In unplasticised PVC, we observed a great difference between suspension and emulsion PVC. These temperature is about 170°C for suspension-PVC and 140°C for emulsion-PVC. Above those temperatures, it is possible to follow the internal structuretransformation of PVC.

### Relationship structure - transformation - viscosity

The temperature where the fusion or gelation of PVC is terminated, defined by viscosity measurements, is strongly influenced by the K-value of PVC. On that point, the polymerisation technique has only a minor influence. Some characteristic values are given in the following table :

TABLE 1 - End-temperature of gelation of PVC

| K-value | Temperature (°C) |
|---|---|
| 58 | 187 |
| 61 | 191 |
| 64 | 193 |
| 66 | 196 |
| 73 | 199 |

Those temperatures are defined by viscosity measurements in dynamic mode on the Rheometrics Mechanical Spectrometer. Some characteristic values are given in Figure 1.

We observed that above those temperatures, the processing of PVC is controled by the standard rheological rules for molten polymers. So, for exemple, we obtained the rule for the viscosity variation in function of the molecular weight of PVC :

$$\eta = C \cdot \bar{M}_w^{3.4}$$

by small values of the shear-rate gradient.

That's give the idea that PVC behaves as a normal molten polymer above those defined temperatures.

## Relationship structure transformation - elasticity

Another factor of importance is the elasticity. We know from other studies of molten polymers that the relationship between the normal stresses versus shear stress is not influenced by the molecular weight, nor by the temperature. By plotting the normal stress versus shear stress, we obtain the same curves for all the suspension-PVC's, and also for all the emulsion-PVC's. The difference observed between the suspension and the emulsion-PVC is a result of the difference in the molecular weight distribution between those two types of PVC. Some representative data are given on Figure 2. On that figure, we can distinguish 3 different regions of structure variation for PVC. This especially when we are looking at the elasticity modulus G defined as

$$G = 2\,\tau_{12}^2/\tau_N \text{ at the same shear stress.}$$

In the first region (T below 190°C), the structure transformations are rather slow. Probably, we obtain here a structure variation in the agglomerates and subgrains of PVC. The second region, for temperatures between 190°C and 205°C, is characterised by rather strong structure transformations. Here we are in the region of fusion of PVC with great transformations on the level of the "primary particles". A third region is localised in the temperature range above 205°C, where the structure transformation is terminated and PVC behaves there as a real molten polymer.

So the most interesting zone of structure variation is localised in a rather narrow range of temperatures. Surprising, the starting temperature of the so-called second region corresponds with the temperature given by the viscosity measurements (Table 1) and is strongly influenced by the K-value of PVC. The end temperature of the second region is between 205 and 210°C and is not greatly influenced by the K-value of PVC.

## PRACTICAL APPLICATION

Typical is the difference in fusion behaviour between suspension and emulsion polymerised PVC. This difference is caused by the presence of emulsifiers in emulsion polymerised PVC. The presence of emulsifiers changes the interparticle potential for attraction and repulsion between the primary particles of PVC. If the attraction forces are large enough, the particles will tend to cluster together in aggregates or flocs. This coagulation process can be counteracted by introducing suitable repulsion forces. Repulsion can be obtained in all media trough adsorption of suitable molecules into the particles. These molecules prevent close contact by steric hindrance.

Above the gelation temperature, where the PVC looks like a homogeneous product and where the viscoelastic flow properties are only fonction of temperature, the internal transformations may still continue. These effects are observable by testing the obtained products in a certain temperature range around 145°C (3, 4).

This complex fusion and flow behaviour of PVC will be illustrated, next to others, by a PVC compound for window-frames developped with an emulsion PVC by Solvay. This PVC formulation gives the possibility :

- to obtain a good dispersion of all the additives ;
- to make a compound which still contain the primary particles, about one micron diameter. These primary particles act as a "processing-aid" during the gelation of PVC ;
- to obtain a good homogeneous product after extrusion without degradation and with a an excellent light stability.

A lot of these characteristics can be explained by the typical fusion process of that PVC formulation. Because of the controled fusion process, the extruded products have a good surface aspect, good flow properties and mechanical properties.

It'is really a good example to illustrate the importance of the fusion characteristics of PVC and the need to know and understand the typical fusion process of PVC.

## CONCLUSIONS

PVC seems to be characterised by three different zones of structure-transformations. In function of the processing-conditions, the PVC is moving from the first region to the second or the third. The flow process can be particulate below the final melting point or controled by the standard rheological rules for molten polymers above its melting point.

Polyvinyl chloride presents a complex supermolecular structure which can be controled during its processing and which creates its interesting possibilities as different end products.

## REFERENCES

1. Geil, P.H., J. Macromol. Sci, Phys B, 14,1 (1977), 171
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4. Benjamin, P., Int. Conf. PVC Proc., London, April 6-7, (1978), preprint, p.B5-1