NATIONAL PHYSICAL LABORATORY

NPL MATERIALS CENTRE

INDUSTRIAL ADVISORY GROUP MEETING ON MEASUREMENT METHODS RELATING TO THE PROCESSING AND PERFORMANCE OF PLASTICS

Minutes of the 3rd IAG and Club meetings held at Rapra Technology Ltd. at Shawbury on Thursday 16th October 2003 at 11.00 am

Participants:

Mr Jim Tetley	Automotive Applied Technologies Ltd
Ms Sandra Young	Automotive Applied Technologies Ltd
Mr Paul Baines	Brand-Rex
Mr Neil King	City University
Mr R P Brown	Elsevier
Mr David Pindar	Federal-Mogul
Dr Keith Wilson	Glynwed Pipe Systems Ltd
Mr John Hockey	Hi-Tech Mouldings Ltd
Dr Alexios Paizis	Imperial College, London
Ms Sharon Turner	Kistler Instruments
Dr Peter Cox	Peter Cox Associates
Ms Elise Carre	Proctor & Gamble
Mr Alec Barron	Railko Ltd
Mr Tim Biswell	Railko Ltd
Mr Mark Edwards	Rapra Technology Ltd
Mr Andi Clements	Rapra Technology Ltd
Mr Andrew Hulme	Rapra Technology Ltd
Mr Keith Smalley	Ross Ceramics
Mr Nuno Lorenco	Land Rover
Mr David Laurenson	Sealedair Ltd
Dr Robin Britton (Chairman)	Synbra Polymers
Dr Justin Furness	The Precise Group Ltd
Mr Robert Hutchinson	University of Sunderland
Dr Alan Wheatley	University of Sunderland
Dr Nick Lavery	University of Wales Swansea
Dr David Isaac	University of Wales Swansea
Mr Chris Brown	NPL
Dr Greg Dean	NPL
Dr Martin Rides	NPL
Dr Sekhar Chakravorty (Secretary)	NPL

Apologies for absence were received from:

Mr J Cubitt	Anglian Windows
Mr R Sturt	Arup
Mr R Dodds	Bodycote Materials Testing Ltd
Mr Nigel Easton	Butser Rubber
Mr BJ Boag	CPV Ltd
Mr J M Paddon	Consultant
Mr Mark Hazel	Du Pont (UK) Ltd
Dr Dilwyn P Jones	Emral Ltd
Mr Michael Collins	G E Ruska
Mr Keith Oakes	Gradus Ltd
Mr Graham Skelhorne	Intelicoat Technologies
Mr David Barnwell	Johnson Matthey Fuel Cells
Dr K H Scrimshaw	KHS Engineering Developments
Mr Bryan Cass	Linpac Plastics
Dr Barry Howarth	Loughborough University
Dr Chris Stevens	NGF Europe Ltd
Mr Neville Blowers	Polypipe Civils Ltd
Ms Emily Boswell	Procter & Gamble
Ms Suzanne Williams	Rolls-Royce
Mr Mick Bowers	Sews-e (x 2)
Dr Neil Witten	Zotefoams Plc.
Dr Colin Lea	NPL

NATIONAL PHYSICAL LABORATORY

NPL MATERIALS CENTRE

Minutes of the 3rd IAG meeting on Measurement Methods Relating to the Processing and Performance of Plastics held at Rapra Technology Ltd. on Thursday 16th October 2003 at 11.00 am

1 WELCOME

Andi Clements (Rapra Technology Ltd.) welcomed all participants to the 3rd IAG meeting of the DTI funded MPP (**M**easurements for the **P**rocessability and **P**erformance of materials) research programme.

2 INTRODUCTION

Robin Britton (Synbra Polymers Ltd.) gave a brief overview of the planned IAG meeting on processing and performance of plastics (Annex 1) and described its overall purpose. The participants were requested to introduce themselves. He pointed out that at this meeting greater emphasis is being given to the heat transfer (MPP 7.1) and the impact (MPP 7.9) projects. At the next meeting, the main focus will be on the rheology (MPP 7.4) and the softness (MPP 7.7) projects.

The minutes of the 2nd IAG meeting held on 19th March 2003 at NPL were accepted as written.

The documents distributed at this meeting are listed in Section 11.

3 UPDATE ON DTI FUNDING OF MATERIALS MEASUREMENT PROGRAMMES

Chris Brown (NPL) gave a brief overview of future DTI measurement programmes in the period 2004-2009. The proposed programmes funded by NMSD (DTI) would focus on three materials metrology areas: ***performance***, ***processing*** and ***characterisation*** (Annex 2). A newly formatted rolling timetable of programme formulation proposed by the DTI was described, which would result in starting one programme each year. The scope and aims of the "Measurement for Materials Performance" programme starting in April 2004 (www.npl.co.uk/performance) and selected themes from this three-year programme including recommended polymer related topics were discussed. It was pointed out that views from the polymer sector were very successful in influencing the proposed spend on polymers in this new programme. Companies were requested to ensure that their views are heard in the future consultation exercises, for example, in the processing programme, which would start in February 2004.

4 HEAT TRANSFER IN POLYMERS (Project MPP 7.1)

Chris Brown (NPL) gave an outline of his talk and briefly discussed industrial needs and objectives of this project (Annex 3). He presented a specification of the heat transfer co-efficient measurement apparatus and discussed details of the engineering design and the progress to its construction at NPL. The scope of the heat transfer co-efficient measurement at surfaces and interfaces was explained with the help of video clips of heat flow in a polymer in the presence of air gaps and thermocouple inserts. Critical factors, which could

influence the measurement of the heat transfer co-efficient were discussed. The scope of the thermal conductivity work was presented with a list of candidate materials, including two thermosets, one rubber, one HDPE powder and two commercial nano-composite materials. Results of uncertainty analysis in thermal conductivity measurements on a HDPE and a PDMS were reported ; the latter material gave a repeatability value of $\pm$1.4%. It is expected that in most materials thermal conductivity measurements can be improved to obtain a repeatability of $\pm$5% or better. The role of process simulation was described with the help of Moldflow video clips of the mould filling analysis and cooling. It was found that a 13% uncertainty in cycle time prediction is typical. However, the results from heat transfer co-efficient studies with Moldflow have remained inconclusive. Initial planning and requirements of industrial demonstrations at Zotefoams and Corus were discussed. The project is expected to take certain cuts in milestones 7 and 10 and in D13.3 worth ~6.8% of the project value due to decant into NPL's new building this summer. A related Eureka project (AIMTECH) involving six UK companies is expected to bring £25K into this project. A project summary was presented at the end.

5 RHEOLOGY OF MULTIPHASE MATERIALS AND POLYMER STANDARDS (Project MPP 7.4)

Martin Rides (NPL) briefly described the project "Processing behaviour of multi-phase materials". He commented that the project would address not just the plastics sector, but also potentially the electronics interconnections industry (soldering and solder replacement), the metals processing industry, the ceramics industry and several other sectors since the flow of multi-phase materials is a common issue to all of them. He reported that the project work would be carried out in collaboration with Loughborough University and Fleming Polymer Testing and Consultancy.

The outcome of analyses of capillary extrusion rheometer results on two filled EVA materials was presented (Annex 4). The experimental results showed that the materials clearly exhibited unusual flow behaviour when using the long extrusion die but not when using the short die test, suggesting that slip was occurring in the shear flow within the long die (but not in the short die where there is very little if any shear flow). The analyses supported the assumption that slip was occurring and indicated that the slip flow accounted for 70% to 80% of the volume flow rate with the remainder occurring by shear flow.

Alan Wheatley (University of Sunderland) asked whether the use of two dies was sufficient for this analysis. Martin Rides replied that he was not content with using just two dies and that further dies would be used in future testing on receipt of those dies. Alan Wheatley also asked about the contribution of extensional flow in the melt flow rate test. Martin Rides commented that in the melt flow rate test the entrance pressure effect accounted for approximately 25% of the total pressure drop. The effect of reducing the die diameter would increase the entrance effect but the purpose of the introduction of the half-length, half-diameter die into the standard ISO 1133 was not to produce identical data but to extend the usefulness of the instrument to higher melt flow rate (lower viscosity) materials.

For a ceramic filled paste complex flow behaviour was observed during testing. Using a conical entry geometry resulted in significantly different "apparent shear viscosities" to those values obtained using the standard abrupt entry geometry. As shear viscosity is a materials property and should be independent of test geometry this obviously demonstrates that these methods are not satisfactory.

Martin Rides then reported on recent developments in ISO Standards on plastics, in particular on rheological test methods. Standards that are currently being developed or revised include:

- Melt flow rate (MVR/MVR) – ISO/FDIS 1133
- Capillary extrusion rheometry – ISO/FDIS 11443

- Extensional viscosity (tensile drawing method) – ISO/DIS 20965
- Drawing characteristics of molten thermoplastics (fibre-spinning method) – ISO/DIS 16790
- pvT (pressure-volume-temperature) – ISO/DIS 11774
- Oscillatory rheometry - ISO 6721-10: published
- On-line viscosity measurement - potential proposal (any industrial interest?)
- Acquisition and presentation of comparable multipoint data: Thermal and processing properties – ISO/FDIS 11403-2
- ISO guide for the acquisition and presentation of design data for plastics - ISO/DIS 17282. Progressing to FDIS
- Determination of no-flow temperature - This proposal has been withdrawn (any industrial interest?)

[Note: the stages of development of a standard are a) NWI – new work item, b) WD – working draft, c) CD – committee draft, d) DIS - draft International Standard, e) FDIS – final draft International Standard, f) ISO – International Standard (published). Technical comments on the standard can be submitted up to and including the DIS stage].

In answer to a question from Alec Barron (Railko), Martin Rides commented that the new melt flow rate standard would be published next year (probably in the Summer). For further information on these and other plastics processing related Standards, please contact Martin Rides at NPL.

Martin Rides concluded that it is intended to run at least one studio project in parallel with this project, on a specific industrially focused topic. For further information on this please contact him.

6 MODELLING THE BEHAVIOUR OF PLASTICS FOR DESIGN UNDER IMPACT (Project MPP 7.9)

Greg Dean (NPL) stated that the main activity in this project will be a comparison of the measured and predicted performance of a plastics component under impact loading (Annex 5). The component chosen is a region cut from an interior panel to a car door supplied by Land Rover. There is interest in the impact performance of this moulding in contact with an occupant in the event of a side impact crash. For preliminary studies, two regions have been identified, and supporting stages have been designed and manufactured to enable the parts to be loaded in a testing machine.

The predictions of deformation will be made using finite element analyses with elastic-plastic models to describe the non-linear and rate-dependent behaviour of the polymer. Three models are being considered. The material properties and parameters required by these models are being determined from tests on standard specimens as well as specimens cut from the component.

A new work item in ISO TC61 has been agreed for the development of an ISO Standard describing the determination of the tensile properties of plastics at high strain rates. A draft has been prepared for ballot based on the procedures developed in a previous project at NPL.

7 MEASUREMENT OF SOFTNESS (Project MPP 7.7)

Martin Rides (NPL) presented a brief review of this project. The key objective is to understand the

relationship between physical properties measurements and sensory perception of soft touch materials in order to predict "feel" (Annex 6). He commented that the project was in collaboration with Prof. Helen Petrie's team at City University.

He explained that using UMIST's Kawabata testing facilities [designed for fabrics] on soft touch polymers had not proved to be as valuable as hoped and thus other methods for determining physical, thermal and mechanical properties data of soft touch plastics had to be developed. The required properties for characterising soft touch were listed. He presented results of measurements of the surface friction behaviour of a range of materials using an instrument recently developed at the NPL. He commented that although the results were for soft touch polymers the instrument could be used to characterise the touch response of a much wider range of materials, e.g. soft touch paints, decorative films and leathers. The results clearly showed a difference between the materials, although a number of measurement issues still need to be addressed. He commented that further improvements to the system were envisaged. Hardness and tensile data were also shown briefly.

Martin Rides then reported on an initial sensory panel evaluation of the feel of various samples by NPL staff. He commented that the main part of the sensory panel work would be done by City University who had expertise in this psychophysical field. The NPL work demonstrated that certain correlations between the various perception criteria could be identified, but also highlighted areas of difficulty in sensory panel evaluations. In particular the vocabulary used was significant in the "success" of sensory panel evaluations.

Jim Tetley (Automotive Applied Technologies Ltd) asked why there was no visual assessment in the softness work. Martin Rides commented that the visual stimulus could play an important role in perception of softness. Some gloss measurements had already been carried out on the samples, and the sensory panel testing had been carried out in a darkened room to remove the visual stimulus. This issue would be included in future sensory panel evaluations.

Alec Barren (Railko) raised the issue of the effect on sensory panel testing of age and other physical attributes of the finger and how this would affect the scorings. Martin Rides commented that the work at City University would investigate the effects of ethnicity and age on sensory evaluation. The low level of consensus in scoring the suitability of the materials for screw driver handle grips resulted in a lack of any strong correlations between this category and the other categories used to describe the material. Nuno Lorenco (Land Rover) enquired whether testing was carried out in any particular order as this might also affect the sensory evaluations. Martin Rides commented that the samples were placed in front of the person carrying out the assessment who could then chose the order in which they examined the samples. The evaluation of the five materials was carried out largely by people comparing two materials at a time until all five materials were ordered on the table in front of them.

Martin Rides commented that there may be a studio project on assessment of the feel of leather, to run in parallel with the core project. For further details on this please contact Paul Tomlins or Martin Rides.

8 "STUDIO" PROJECTS RELATING TO POLYMERS

Chris Brown (NPL) gave a brief overview of the DTI funded collaborative research opportunity called "Materials Measurement Studios" (Annex 7). The objectives, operational framework and scope of the "Studio" projects were explained. All UK companies are eligible to apply and the application is open throughout the year. The details of participation criteria, commitments and funding arrangements were discussed. A list of past and present projects relating to polymers and the source of obtaining further information were given (see Annex 7).

9 ON MACHINE

Justin Furness (The Precise Group Ltd.) gave an overview of this DTI initiative, where it is aimed to demonstrate the practical benefits of better measurements to companies, which will enable them to improve productivity, increase profit and win new business (Annex 8). The scheme is supporting the National Measurement System and is run by On-machine Measurement Ltd., part of the Precise Group of companies in association with NPL. Successful projects have already been run in West Yorkshire, St. Helens and Bristol and the programme is now expanding into new sectors (particularly the polymer sector) and new regions. Further details of this measurement programme can be found in www.on-machine.co.uk (tel: 0800 072 8590 ; e-mail: info@on-machine.co.uk).

10 FUTURE MEETINGS, AOB & DATE OF NEXT IAG MEETING

Robin Britton (Synbra Polymers Ltd.) thanked Rapra Technology Ltd. for kindly hosting this IAG meeting. He invited all to attend the next IAG meeting and thanked everyone for their presence today before closing the meeting.

There was no other business to discuss.

The next IAG meeting would be held on :

[The proposed date for the next IAG meeting was Wednesday 25th February 2004 at the meeting, which has since been changed to the following new date due to staff unavailability.]

Thursday 4th March 2004 at NPL ⇐ Please note the change of date

The meeting will start at 10.45 am (coffee / tea available from 10.15 am). An agenda will be circulated one month prior to the meeting. All are invited.

11 DOCUMENTS AVAILABLE

The following documents were distributed at the meeting:

1. Agenda
2. List of Participants
3. Presentation slides of speakers (see Annexes)
4. Final project overview: "*Viscoelastic measurement techniques for polymer melts*", 2003.
5. NPL Handout : '*Processing behaviour of multi-phase materials*', September 2002
6. NPL Handout : '*Getting to grips with soft-touch materials*', September 2002
7. NPL Handout : '*Heat Transfer in Polymers*', September 2002
8. NPL Handout : '*Collaboration in materials measurement*', September 2002
9. M Rides: "*The effects of thermal conductivity and heat transfer coefficients on polymer processing*", NPL measurement note CMMT(MN)023, September 1998.
10. C Hobbs: "*Ultrasonic Cure Monitoring of Two Industrial Processes*", NPL measurement note MATC(MN)044, January 2003.

11. T Fry and C Brown: "*Measurement Methods Relating to the Processing of Plastics: The measurement of reactive polymer systems*", July 1999.
12. C Allen and C Hobbs: "*Thermal Properties of Polymers, Part 1: Industrial Guide to Measurement by Differential Scanning Calorimetry (DSC)*", NPL measurement note CMMT(MN)058, December 1999.
13. Sekhar Chakravorty: "*New DTI funded NPL Studio collaborative projects: requirements*", October 2003.
14. C Brown and S Percio: "*Heat Transfer in Polymer Processing: The Importance of Accurate Measurement*", Polymer Rheology Conference, 2001.
15. A Dawson: "*Uncertainty Budget for Thermohaake Thermal Conductivity Apparatus*", NPL report, October 2003.
16. S Chakravorty: "*The quality of PVT data: an assessment*", an article in British Plastics & Rubber, February 2002.
17. S Chakravorty: "*PVT testing of polymers under industrial processing conditions*" Polymer Testing, vol. 21, p 313-317, 2002.

Copies of any of the above documents can be sent to members of the Polymer Processing and Performance Measurement Club unable to attend the meeting. Please write, phone (020 8943 6919), fax (020 8943 6046) or e-mail (sekhar.chakravorty@npl.co.uk) Sekhar Chakravorty indicating which document(s) you require.

ANNEXES

DISTRIBUTION

Mr Johan Palm / Dr A Ericsson	ABB High Voltage Cables AB
Mr Julian Cubitt	Anglian Windows Ltd
Mr R Sturt	Arup
Mr Jim Tetley / Ms Sandra Young	Automotive Applied Technologies Ltd
Mr Kuldip Chahal	Autotype International Ltd
Mr Martyn Bennett	Avon Rubber Plc
Mr Fred Moran	AWE plc.
Dr Alan Smith	AZ-Tech
Mr Paul Addison	Beardow & Adams (Adhesives) Ltd.
Mr John Wrobel	Bespak Europe Ltd
Mr Paul Adams/Mr K Simpson	Bespak Plc
Mr S M Davies	BICC Brand Rex Ltd
Mr Glynn Bonnington	BIP Amino Moulding Powders
Mr Michael Shaw	BIP Ltd
Mr John Webb	Blagden Speciality Chemicals Ltd

Mr R Dodds	Bodycote Materials Testing Ltd
Mr S Eggen	BOREALIS
Dr Phil Hope	BP Chemicals Ltd
Dr Choon K Chai	BP Chemicals S.N.C
Mr Paul Baines/Mr Paul McMullan	Brand-Rex Ltd
Dr Peter Allan	Brunel University
Mr Peter Mayor	Building Performance Group Ltd
Mr Nigel Easton	Butser Rubber Ltd
Mr Smith	Cabot Plastics Ltd
Mr Stephen Robinson	Carl Stuart UK Ltd
Mr A Rakowicz	Castrol Ltd
Prof. Helen Petrie / Mr Neil King	City University
Mr J M Paddon	Consultant
Mr Andrew Legg	Coolmation Ltd
Mr Byron Williams	CORUS
Mr B J Boag	C P V Ltd.
Mr B Gillies	Crown Cork and Seal Co Inc
Mr James Anderson	CRP Marine Group Ltd.
Mr Colin Muse/Mr Robert Richards	Delcam UK
Mr R M Griffiths	Delta Electrical Ltd.
Mrs Joan Cocksedge	Department of Trade & Industry
Mr. Derek Bates	DRB Materials Technology Ltd.
Mr Mark Hazel	Du Pont (UK) Ltd
Mr R P Brown	Elsevier Science Ltd
Dr Dilwyn Jones	Emral Ltd
Mr Jo Martin / Mr Scott Langley	Englemann & Buckham Ltd.
Mr Stephen Matthews	Eternit UK Ltd
Mr David Pindar	Federal-Mogul
Dr Don Fleming	Fleming Polymer Testing & Consultancy
Mr Barry Hennessey/Mr Alan Harrison	Ford Motor Co. Ltd
Mr Michael Collins	G E Ruska
Dr Keith Wilson	Glynwed Pipe Systems
Mr Mick Bull	Glynwed Pipe Systems, Cannock
Mr Keith Oakes	Gradus Ltd
Mr John Hockey	Hi-Tech Mouldings Ltd
Mr David Abraham	Honda R&D Europe (UK) Ltd
Dr. Alexios Paizis	Imperial College, London
Mr Graham Bailey	Industrial Dielectrics (UK) Ltd
Mr Graham Skelhorne	Intelicoat Technologies
Mr David Barnwell	Johnson Matthey Fuel Cells
Dr K H Scrimshaw	KHS Engineering Developments
Ms Sharon Turner / Mr M Winters	Kistler Instruments
Mr. Nuno Lorenco	Land Rover
Mr Lee Malon	Linpac Mouldings
Mr Bryan Cass	Linpac Polymers
Mr Mark Bartlett	Lloyd Instruments Ltd
Mr Nigel Weedon	Longcliffe Calcium Carbonates
Mr Barry Howarth	Loughborough University
Dr Ian Robinson	Lucite International UK Ltd
Mr Roy Carter	Magna Projects & Instruments Ltd
Mr E Haig	Manuplastics Ltd

Mr Tony Kosari/Mr Mike Rogerson	Micropol Ltd
Mr Eric Henry/Mr Nick Smith	Moldflow (Europe) Ltd
Dr Alan Chapman	Morgan Materials Technology Ltd
Dr Chris Stevens/ Mr D Mason	NGF Europe Ltd
Mr S Ruck / Dr P Jeffries	Nokia UK Ltd
Mr D Netsha / Mr I Tomic	Nylacast R & D
Mr Richard Chadwick/Mr Japala	Nylacast Ltd.
Mr Paul Clark	Perkin Elmer
Mr Paul Gabbott	PETA Solutions
Dr Peter Cox	Peter Cox Associates
Dr Paul Holmes	Pilkington PLC
Mr Tony Carroll/Mr R A Lawrence	Polyone Engineered Materials UK Ltd
Mr Paul Roberts/Mr Neville Blowers	Polypipe Civils Ltd
Mr Peter Prentice	Polytech Consultants Ltd
Mr Alan George/Mr P Duffy	Porpoise Viscometers Ltd
Ms Emily Boswell/Ms Elise Carre	Procter & Gamble
Mr Alec Barron / Mr Tim Biswell	Railko Ltd.
Mr Mark Edwards/Mr M Gaddes	Rapra Technology Ltd
Mr Andi Clements/Mr Andrew Hulme	Rapra Technology Ltd
Mr Keith Smalley	Ross Ceramics Ltd
Ms Charlotte Priestnall	RPC Containers Ltd
Mr Mark Walsh	R-TEK
Mr Michael Collins	Ruska Instrument Corporation
Mr David Laurenson	Sealedair Ltd
Mr Mick Bowers	Sews-e
Dr Robin Britton	Synbra Polymers Ltd
Mr D Bell/Dr B Costello	T A Instruments Ltd
Dr Justin Furness	The Precise Group Ltd
Dr A Muhr / Dr M Fernando/ Dr J Gough	TARRC
Mr D Ball/ Mr B Arnold	Texon UK Ltd
Mr Kevin Barber	Thermo Prism
Dr Sudhir Mani	Unilever Research (Port Sunlight)
Mr Robert Hutchinson/ Dr Alan Wheatley	University of Sunderland
Dr N Lavery/ Dr C Arnold/ Dr D Isaac	University of Wales, Swansea
Dr S Lackovic/Mr J Hulbert/Mr J Jackson	Wallace Instruments
Dr. Neil Witten	Zotefoams Plc.
Dr Colin Lea	NPL
Mrs G Tellett	NPL
MATC, MPP Polymer Projects Staff	NPL

Sekhar Chakravorty
30th October 2003
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