Appendix 1 – Developments in EU and UK legislation applying to polymers containing BFRs

Outcomes of the third UK consultation on the WEEE Directive

The UK Government's third UK Consultation on the WEEE Directive discussed issues concerning :-

- transposing the Directives in Autumn 2004
- registration of producers and data reporting from producers from start of 2005, especially sales data for 2004 in order to calculate market share
- establishing a National Clearing House

The Environment Agency also consulted on draft guidance for the treatment and storage of WEEE at treatment facilities[1]. The draft guidance included the following proposed requirements:

- removal of fluids and certain substances
- systems for treatment must use Best Available Treatment Recovery and Recycling Techniques (BATRRT), which will be further defined in guidance from Defra.
- treatments must ensure compliance with Article 4 of the Waste Framework Directive (75/442/EEC) – waste is recovered or disposed of without endangering human health or the environment. Also, the Council Regulation No. 2037/2000 (as amended) on Ozone Depleting Substances, Council Directive on hazardous waste (91/689/EEC) and possibly the European Waste Catalogue distinction between hazardous and non-hazardous entries.
- treatment processes must comply with The Management of Health & Safety at Work Regulations 1999, The Control of Substances Hazardous to Health Regulations 1999 (COSHH) and The Manual Handling Regulations 1992.
- treatment operations will require a permit (unless an exemption has been provided)

An EA/SEPA Consultation Draft on Guidance on Treatment of WEEE was also published in July 2004. Requirements in this draft guidance include:-

- treatment operations to be conducted at an authorised treatment facility (ATF) with a permit
- Annex III of the Directive covers criteria concerning sites for storage, sites for treatment. This includes acceptable and unacceptable criteria
- site operators will have a data reporting requirement
- priority to be given to re-use of whole appliances and then components, sub-assemblies and consumables
- all separately collected WEEE that is not designated for re-use as whole appliances must be sent for treatment
- systems for treatment of WEEE must use Best Available Treatment Recovery and Recycling Techniques (BATRRT) – to be further defined via an amendment to the Waste Management Licensing Regulations 1994, with Consultation in September 2004
- treatments must ensure compliance with Article 4 of the Directive ; waste is recovered or disposed of without endangering human health and the environment
- treatment must avoid the dispersion of pollutants into the recycled material or the waste stream
- fluids must be removed prior to crushing or shredding
- The following specific items to be removed :-
    - capacitors containing polychlorinated biphenyls (PCBs)
    - switches or lamps containing mercury
    - batteries
    - liquid and paste (balk and colour) from toner cartridges
    - plastic containing brominated flame retardents
    - asbestos
    - cathode Ray Tubes (CRTs) and also the fluorescent coating in the CRT

[1] www.environment-agency.gov.uk/yourenv/consultations/830820/

- CFCs, HCFc, HFCs and HCs from refrigeration and cooling systems
- gas discharge lamps + mercury
- Liquid Crystal Displays (LCDs) if they have a surface area greater than 100 square centimetres or back-lighted with a gas discharge lamp (this may be amended by the European Commission)
- external electric cables
- components containing refractory ceramic fibres
- components containing radioactive substances
- electrolyte capacitors

- The recycling target for modern mobile phones can be achieved by recycling the battery.
- Requirements for removal of printed circuit boards are under priority review

Following the consultation process concerns were raised about several practical issues and also the legality of the Clearing House concept in EU law.

In February 2005 the Government announced that proposals for a National Clearing House needed simplifying.

In March 2005 several Local Authorities expressed concern that WEEE proposals might be put back to 2006, especially in terms of funding any upgrades to civic amenity sites.

They were also concerned about lack of investment in 'new technologies' to re-manufacture and/or recycle and/or recover WEEE.

In March 2005 DTI confirmed that :-

- new WEEE regulations would be completed later in 2005
- implementation of producer responsibility would be put back, to start on 26th January 2006
- the WEEE Directive would be transposed into UK law in summer 2005, accompanied by non-statutory guidance
- producers would have to mark equipment to show it was put on the market after 13th August 2005
- a National Clearing House would not be established, because of “the complexities and public accountability implications”
- allocation of WEEE to producers will probably involve “… a mix of physical allocation (WEEE collection sites) to larger producers and compliance schemes with a settlement mechanism enabling financial compliance by producers with smaller market share-based obligations”
- DTI still had some concern that any compliance scheme would be dominated by large producers, who will collect up all of the WEEE and then hold smaller manufacturers to ransom
- a Consultation Paper would be issued on draft regulations, and DTI, Defra and the Environment Agency would work with Local Authorities to clarify issues surrounding the July 2005 Waste Acceptance Criteria, which adjust the categorisation of hazardous wastes
- producers will be expected to make 'reasonable estimates, capable of corroboration' of the number of units put onto the market during 2004, and the allocation to households or businesses
- producers reported weights of household equipment put on the market wouldbe used to calculate their obligations relating to household WEE arisings in the UK (not confirmed as yet whether this will be for all WEEE or the four WEEE groupings, especially as nearly 50% of household WEEE are small items normally put in the dustbin)
- producers would register with the Environment Agency, rather than the National Clearing House or DTI
- the role of civic amenity sites as Designated Collection Points should be agreed by April/May 2005, with the British Retail Consortium (BRC) funding a retail compliance scheme, including finance to upgrade civic amenity sites. Issues of take-back and reuse have still to be finalised. BRC estimate that current proposals could cost as much as £750 million
- DTI would follow a voluntary approach to the operation of visible fees covering the cost of recycling equipment, and will broker discussions between producers and retailers on how the system could operate

The revisions were welcomed by businesses, with some wanting the start delayed until after the busy Christmas period, preferably in April 2006.

In October 2005 industry proposed the concept of an arms-length 'national settlement centre' to help with producer responsibility for WEEE. Producers or compliance schemes could collect any amount of WEEE arising at a collection point regardless of their actual obligation, with compensation for any excess or payment for under-achieving being managed through such a centre, based on average costs for collected tonnages. As at November 2005 DTI was proposing a similar 'allocation systems' with larger companies collecting WEEE from designated collection facilities and passing some costs to smaller companies, perhaps using a free market system for evidence of compliance – similar to PRNs.

Experts claim that just over 1,000 sites will be needed to receive WEEE waste, and with 1,072 civic amenity sites the option of upgrading these sites to accept WEEE has been the favoured option of the retailers. However, several Local Authorities have been quoted between £500,000 and £1 million for upgrade to single sites : some are too small, five separate containers are required and also additional staff. In addition, Local Authorities argue that they do not have targets for WEEE and the obligation (and costs) must rest with producers and retailers.

In May 2005 BRC established a fund for retailers to contribute into, and for payments to Local Authorities. The fund will be for £8.2 million over three years, with one-off payments of £5-6,000 to upgrade civic amenity sites. These amounts contrast with earlier estimates of contributing £5 million per annum over five years. The fund will also be used to support public education and special events to further enhance and improve the collection of WEEE. LARAC was “incredibly disappointed” at the amount of funding being offered, and many Local Authorities may not wish to participate.

In August 2005 LARAC argued that Local Authorities were being forced to register their civic amenity sites as Designated Collection Facilities (DCFs), so that retailers can claim an adequate collection network has been established. LARAC has written to Defra with various proposals : no site would be refused registration as a DCF, sites could sign up any time to be a DCF, signing-up would be for specific time periods, for sites designated as DCFs retailers and producers would control the specification of the sites and effectively controlling the costs involved.

Defra stated in October 2005 that it will leave consumers to police the legal requirements for small retailers to provide free take-back for WEEE after June 2006 – if they have not joined a compliance scheme and if they fail to take back WEEE or inform the consumer of a nearby collection point. This may involve c. 9,000 retailers, with less than 1% of retailer obligations. In contrast to packaging there are no threshold values for quantities of WEEE.

The Department of Trade and Industry announced on 10th August 2005 that manufacturers and retailers will now be responsible for the collection and recycling of WEEE from June 2006 rather than January 2006. According to the DTI, the postponement of six months has been made in the light of preparations needed for the European-set legislation. One of the main reasons for the delay is also to allow the retailers, led by the British Retail Consortium, to establish an adequate network of facilities for separate collection of WEEE for householders to use.

In the light of this announcement, the DTI said it will cover "new burden" costs incurred by Local Authorities for separately collecting electronic waste that has been newly classed as "hazardous" since changes to landfill regulations came into force in July 2005. One issue still to be clarified is that of Ozone Depleting Substances associated with fridges. The European Commissioner announced in November 2005 that all liquid and gaseous hydrocarbons must be removed from refrigeration equipment, including cooling circuits and insulation before further treatment and/or safe disposal.

A survey by letsrecycle in August 2005 indicated that the price for recycling a single CRT is between £3.50 and £7, with the debate focussing on whether to charge per unit or per tonne. Some companies (e.g. Sims Group) offer both, with transport costs being the main variable in charging and size also influencing the charge made by some companies.

Alongside BRC proposals, REPIC announced that they would provide Local Authorities with civic amenity sites allocated to them as designated collection facilities free collections and collection containers. Where sites are too small five separate “piles” of WEEE could be collected on a ”round robin” basis. The five containers would be for:

- Cooling appliances : fridges, freezers
- other large domestic appliances : cookers, dishwashers, washing machines
- cathode ray tubes : televisions and monitors
- small domestic and mixed appliances : tools, hairdryers
- lighting : fluorescent tubes, energy saving light bulbs

In July 2005 the European Commission formally asked eight Member States (Estonia, Finland, France, Greece, Italy, Malta, Poland and the UK) to transpose into their national laws three EU Directives tackling the environmental problems caused by the growing amount of electronic and electrical waste. This should have been done by 13 August 2004. If a Member State fails to comply with this request, the Commission could take it to the European Court of Justice.

The Directives in question aim to ensure that e-waste, which often contains hazardous materials, is not simply thrown away, but is collected, recycled and reused, with the remaining waste being properly treated. The actions are part of a series of environment-related infringement decisions against several Member States which the Commission is currently announcing. Environment Commissioner Stavros Dimas said: “Nobody wants to see old computers and television sets piling up at the roadside and polluting the environment. Therefore efficient collection and recycling/reuse is necessary. Member States have agreed on ambitious legislation to tackle the problems caused by rapidly growing amounts of E-waste. But they also have to do the follow-up work and implement what they have agreed.”

EU legislation on electrical and electronic waste : In 2002, the Council and European Parliament adopted the Directive on Waste Electrical and Electronic Equipment (WEEE Directive). This Directive requires Member States to ensure the establishment of systems for the collection of e-waste (by August 2005). Furthermore, they have to ensure its reuse, recovery and recycling, and the sound disposal of the remaining waste. When the collection systems are in place, consumers will be able to take these products back to shops and collection points for free. The Directive also sets collection, re-use and recycling targets and outlines the financial obligations of producers. A 2003 amendment to the WEEE Directive further clarifies those obligations with regard to the financing of professional (i.e. non-household) equipment.

Each EU citizen currently produces around 17-20 kg of e-waste per year. Some 90% of this waste is still landfilled, incinerated, or recovered without any pre-treatment. This allows the substances it contains to make their way into soil, water and air where they pose a risk to human health. The transposition of all three Directives was due before 13 August 2004. France, Italy and the United Kingdom have failed to transpose all three Directives. Finland has not yet transposed the three Directives in the province of Aland. Greece has transposed the earlier WEEE and RoHS Directives, but not the amendment to the WEEE Directive. Estonia, Malta and Poland have transposed the RoHS Directive but not yet the WEEE Directive and its amendment. The Commission has therefore sent final written warnings - the last step before referral to the European Court of Justice - to the eight Member States.

An interim report published by ICER in March 2005 (funded by Biffaward) suggests that the amount of WEEE thrown away by households is twice the figure previously thought – amounting to 1 million tonnes, or 16 kg per person. Other comments from the report :-

- many items are less than 2 kg and are thrown in the dustbin with other household waste
- over two-thirds of the tonnage thrown away by household come from just 3 out of the ten categories : 78% = large household appliances (washing machines, fridges, cookers), 13% = consumer equipment (mostly TVs), 8% = small household equipment, 7% = IT/telecomms, 4% = tools, lighting, toys, etc
- WEEE Directive focuses recovery and re-use producer obligations on separately collected WEEE
- producer obligations (50,000 in UK) are calculated on the basis of market share
- costs of treating and recycling estimated to be up to £83 million, including £27 million for TVs and monitors containing cathode ray tubes (CRTs)
- costs for treatment and recycling of household WEEE : £5 per fridge, £7 per CRT, 30-40 pence for lighting. This compares with most other WEEE at £100-200 per tonne

Progress on the implementation of the Waste Electrical and Electronic Equipment Directive (known as WEEE) is to be reviewed immediately, Energy Minister, Malcolm Wicks said 15th December 2005.

The WEEE Directive requires producers to pay for treatment and recycling or recovery of all WEEE products. Retailers have an obligation to offer take-back services to householders and will be providing a network of collection facilities where consumers can take back their WEEE for it to be collected separately from other municipal waste.

In announcing the review, Malcolm Wicks said: "This Government is firmly committed to sustainable development and recognises that effective implementation of the WEEE directive has a key role to play in achieving this goal. The Directive is challenging and effective implementation of its obligations requires a lot of planning and preparation - it is vital that the producers, retailers and the waste industry together with Government have the appropriate plans, infrastructure and regulations in place. We have listened to the concerns expressed by both the business community and other stakeholders over the implementation process and have decided that more time is needed to get the implementation right. Although any further delay is regrettable, this will ultimately deliver far greater environmental benefits. My officials will be working closely with colleagues from Defra and the Environment Agency which will form the basis for a formal consultation on draft regulations and guidance in the Spring."

“The Government recognises that this has implications for the burdens placed on Local Authorities to dispose of separately collected WEEE. We announced previously that DTI would meet Local Authority New Burdens costs in the light of Ministerial decisions to defer the WEEE implementation. Specifically, we have said that DTI will meet any costs to Local Authorities of arranging the treatments required for any televisions and PC monitors containing cathode ray tubes and fluorescent lamps which they collect separately (rendering these "hazardous") and sent to a hazardous waste landfill, in advance of the WEEE Regulations introducing producer responsibility for these costs, i.e. where local authorities have chosen to collect separately these categories of WEEE in the absence of any legislative requirement at this stage.”

“We have already agreed with Local Authorities that payment for costs incurred in 2005/06 will be included in the annual settlement figure for 2006/07. We will continue to work with Local Authorities to establish the costs associated with the decision to undertake this review.”

Additional regulations - WEEE Permitting regulations - are to be made by Defra, together with guidance on treatment operations. The Regulations will come into force alongside the producer responsibility requirements of the DTI WEEE regulations and will introduce the treatment permitting requirements of the WEEE Directive.

Government awarded Local Authorities £14.7 million to cover the cost of collecting hazardous WEEE from August 2005 – 1st June 2006.

28th March 2006 DTI published its Conclusions of Implementation Review + Implementation Proposals. A formal consultation will follow in ‘Spring’ 2006.

- strong support for producer and retailer responsibility.
- approved compliance schemes for retailers, to establish Designated Collection Facilities (DCFs) – majority in existing civic amenity sites and/or transfer stations. SMEs to be involved in compliance schemes, with

proportionate membership fees. A subsequent paper will cover approval criteria for compliance schemes. Or, retailers may take WEEE from households when selling new EEE

- obligatory registration for producers with EA – direct or via a (single) compliance scheme. Approval criteria for compliance schemes will be set out in a subsequent paper. Producer compliance schemes will negotiate with Local Authorities to collect sufficient WEEE
- a system for calculating producers' obligations, based on calendar years and including weight of EEE placed on the market in the preceding year. Quarterly reports to be published by EA
- a quasi-market mechanism for allocation WEEE from DCFs – a fall-back system if sites are not cleared, with Local Authorities able to recover costs from the 'central exchange' system (WEEE-RNs similar to PRNs ?)
- a code of practice covering the collection of WEEE from DCFs
- a network of Authorised Treatment Facilities, which will process WEEE and provide evidence to producers
- protocols to enable producers to demonstrate achievement of recycling targets in a cost effective way
- a voluntary approach for producers to show the cost of handling historical ('orphan') WEEE, with freedom through supply chain negotiations on how to display the costs involved
- role of voluntary groups in re-use of WEEE to be maximised

Following the release of the *Conclusions of the Implementation Review* paper on 27th March 2006, the DTi issued a further *Supplementary Paper* in May 2006, taking into account views expressed by stakeholders during the initial consultation period

The key changes made to the proposal issued in March 2006 are:

- a proposal to calculate producer obligations through five categories of WEEE rather than total tonnage : large household WEEE containing ozone-depleting substances, large household WEEE not containing ozone-depleting substances, televisions and monitors, fluorescent tubes, all other WEEE
- the term 'retail compliance scheme' to be replaced by 'Distributor Deposit Scheme' (to avoid confusion with producer compliance schemes)
- empowering the Secretary of State to appoint a distributor deposit scheme operator rather than approving applications and the intention to make an early appointment
- safeguards to discourage a producer compliance scheme from handling levels of WEEE greatly exceeding their member's obligations, with a limit of over-collection of 5% of the market
- a more detailed policy approach to 'business to business' implementation. Producers will only be responsible for such WEEE if the items were purchased after 13th August 2005, otherwise producers will only be responsible for collecting WEEE if it is being replaced on a like-for-like basis. Business end users are likely to have their responsibilities confirmed within waste Duty of Care regulations, with Defra issuing a coinsultation shortly
- further clarification on the role of collection facilities, with the DCF network roughly equivalent to the number of existing civic amenity sites and a code of practice is being drawn up. DTI recognises the 'disquiet' over proposals to allocate £6,000 for each DCF as being 'an unrealistic figure in relation to the real costs on the ground'.
- producer compliance schemes
- the form of evidence used for collection and recycling from authorised treatment facilities will be evidence notes to producer compliance schemes regarding the recycling of WEEE collected from DCFs. A central exchange will be established to purchase evidence notes (at cost) from producers and refunding Local Authorities as appropriate

The Implementation Team requested further comments from stakeholders on the *Conclusions to the Implementation Review* and the *Supplementary Paper*, especially with regard on the following issues:

- are the proposals workable?
- if not, which elements need further consideration?
- what additional factors need to be considered in order for the proposals to work effectively?
- are there any loopholes that have been overlooked?
- are there any contradictions between the various parts of the process?

Comments had to be submitted to,the DTI before 19 May 2006, in preparation for a full consultation in Summer 2006.

Of more general relevance, proposed new **Hazardous Waste Regulations** were published by Defra in August 2004, and were implemented in 2005. The 1996 **Special Waste Regulations** were intended to transpose the Hazardous Waste Directive (91/689/EEC) and the EC Hazardous Waste List (94/904/EC). On 1st January 2002 changes to the Hazardous Waste List were applied in the EU and the list was incorporated into the **European Waste Catalogue** (01/573/EC amending 00/532/EC and replacing 94/3/EC). In addition to replacing the term 'special waste ' with 'hazardous waste', the new regulations:

- mean that more waste items from businesses will be classed as hazardous waste, e.g. batteries, used oil, fluorescent tubes and computer monitors.
- where hazardous waste is mixed with non-hazardous waste, the whole skip becomes hazardous waste unless or until the hazardous component(s) are separated from the non-hazardous waste.
- make businesses who produce waste more aware of the waste they are producing through a requirement to notify (register with the Environment Agency). Waste carriers will not collect from unregistered producers. This will help to improve the 'cradle to grave' audit control of hazardous waste as required by the Directive
- encourage reduction in the amount of hazardous waste being produced by industry and businesses
- reduce the current administrative burden

These new regulations exclude domestic waste rather than household waste : the former being from accommodation used purely for living purposes (and without commercial gain), whilst the latter includes premises such as church halls, residential homes, camp sites, prisons and building used for public meetings and by charities.

Reference to Authorised Treatment Facilities is also relevant in the context of end-of-life vehicles (ELVs), and the requirement to de-pollute such vehicles prior to any recovery operations. Traditionally, end-of-life vehicles and various categories of WEEE have been handled through metal scrapyards with items being shredded to facilitate metal separation. Some of these sites operate to very high standards of environmental protection, some have full waste management licenses, some are exempt and some do not meet the standards set in the ELV Regulations 2003. A year-long amnesty ended on 31st October 2004, and during a campaign in Yorkshire in October 2004 the Environment Agency found that of 170 sites visited, 130 did not comply with their licences and a further 23 were operating illegally.

At a global level, the Stockholm Convention met in Tokyo in October 2004 to consider classifying vehicle shredding as a major source of persistent organic pollutants. If accepted by the United Nations summit in Uruguay in May 2005, this would give the UK two years to phase out their use.

One problem from such operations is the residual waste, usually referred to as Automotive Shredder Residue (ASR). Problems occurred in July 2004 with some landfill sites refusing to accept such material as it was considered to be hazardous waste, and new regulations (with effect from 16th July 2004) meant that co-disposal of hazardous and non-hazardous wastes was no longer possible. Some shredder companies were considering not accepting any ELVs for shredding. Following various meetings, the Environment Agency agreed to class this residue as non-hazardous under certain conditions, where shredders can demonstrate that their waste residues are non-hazardous through approved and suitable tests :-

- either because the waste residues arise from vehicles which have been de-polluted and hazardous materials removed in accordance with the DTI/Defra de-pollution guidance, and demonstrated in a waste transfer note when passing the reside to landfill operators. To apply with effect from 1st November 2004, subsequently extended to 1st December 2004.
- the waste residues are from other inputs which do not contain hazardous materials
- a three-month window (initially until 1st November 2004, and then extended to 30th November 2004) was agreed during which a simplified de-pollution checklist can apply where companies have yet to develop the capability to comply with the ELV Regulations 2003 : vehicle shredder waste will be classed as non-hazardous if it does not contain lead acid batteries, components identified as containing mercury (e.g. switches), engine oils and oil filters and fuel
- after 1st December 2004 all ELVs will have to fully de-polluted to the government set standards as set out in the ELV Regulations 2003. If not, ASR will have to be sent to a hazardous-only landfill site or authorised incinerator

In March 2006 the European Commission announced a period of consultation over possible exemptions of an annex to Directive 2002/95/EC of the European Parliament and of the Council on the restriction of the use of certain hazardous substances (ROHS) in electrical and electronic equipment.

Article 4(1) of Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment (1) provides 'that from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, PBB or PBDE.' The annex to the Directive lists a limited number of applications of lead, mercury, cadmium and hexavalent chromium, which are exempted from the requirements of Article 4(1).

According to Article 5 (2) of Directive 2002/95/EC the Commission is required to consult the relevant stakeholders before amending the annex. The results of this consultation will be forwarded to the Technical Adaptation Committee of the Directive 2002/95/EC and the Commission services will provide an account of the information received. Although the Commission will analyse the results of this stakeholder consultation carefully, please note that as with all stakeholder consultations, this action is only one part of the decision making process.

Proposal for additional exemptions

Article 5(1)(b) of Directive 2002/95/EC provides that materials and components can be exempted from the substance restrictions contained in Article 4(1) if their elimination or substitution via design changes or materials and components which do not require any of the materials or substances referred to therein is technically or scientifically impracticable, or where the negative environmental, health and/or consumer safety impacts caused by substitution outweigh the environmental, health and/or consumer safety benefits thereof.

On the basis of this provision the Commission has received from industry additional requests for applications to be exempted from the requirements of the RoHS Directive. The titles for the exemptions as submitted by industry and the request for exemptions are:

1. Cadmium and cadmium oxide in thick film pastes used on beryllium oxide substrates until January 1, 2008;
2. Gaskets of butyl rubber material vulcanised with chinondioxim and lead tetraoxide, for use in Aluminium Electrolytic Capacitors;
3. Sharp LQ104X2LX11 (formerly Fujitsu FLC26XGC6R-01);
4. Quartz Crystal Resonator and in Fine Pitch Electronics Systems used in the Swiss Watch Industry;
5. Cadmium in opto- electronic components;
6. Transducers used in professional loudspeaker systems, using tin-lead solder;
7. Tin-lead solder in the manufacture of professional audio equipment;
8. Components used in the manufacture of the Hog1000, Hog500, Event416, Event408, ESP2-24 and ESP2-48 lighting control consoles;
9. Specific modular units, including tin-lead solder, being used in special professional equipment;
10. Inventory of special ICS having tin-lead solder on/in leads/balls, used in specialist/professional equipment;
11. Cadmium Mercury Telluride;
12. Lead contained in Babbit lined bearings;
13. Cadmium alloys as electrical/mechanical solder joints to electrical conductors located directly on the voice coil in transducers used in high-powered loudspeakers;
14. Thermal cutoff with a fusible element that contains lead (and possibly cadmium, mercury and hexavalent chromium) for applications where normal operating temperature exceeds 140 C and reliable, predictable, operation for a minimum of 30,000 hours is required;
15. Mercury free flat panel lamp;
16. Electronic equipment where the reliability, durability and longevity of the equipment is paramount;
17. Semi Red Brass C84400, 81-3-7-9 or a similar Brass material. Used on radio frequency line sections;
18. Lead is used as an alloy to the copper in 6 to 8 % by weight. Needed for casting and machinability characteristics;
19. Lead in solders for electronic equipments used for the monitoring, the protection and the safety of people in healthcare, telecare and emergency calls domains in professional and private sectors;
20. FPGA devices manufactured by Xilinx (XC5202-6VQ100C, XC4003E-3VQ100C and XC4013E-3PQ240C) containing lead solder (Pb) used in the plating of the device terminations;
21. Lead oxide in seal frit used for making window assemblies for argon and krypton laser tubes;
22. Smart card readers (product: GemSelf700-MS2, GCR700-3ZS, Vodafone D2 , GCR760 and GemSelf750 SV);
23. Use of mercury in Babcock's DC plasma displays and use of Lead Oxide (PbO) in Babcock's DC plasma displays frit seal.

The Commission' Environment Directorate invited interested parties to send their comments by 15 May 2006 at the latest by e-mail to ENV-RoHS@cec.eu.int   or by post to:

European Commission, DG Environnent, Unit G4 - Consultation Directive 2002/95/EC, B-1049, Brussels, Belgium.[2]

[2] http://europa.eu.int/comm/environment/waste/rohs_5_consult.htm

Developments regarding WEEE recycling in the UK since January 2004

This is an attempt to provide a chronological review of developments and initiatives relating to practical implementation of WEEE recycling in the UK.

European Recycling Platform (ERP)

- Sony, Braun, Electrolux and Hewlett Packard as founder members = established in November 2002 = 14% share of European electrical goods market.
- Contributed to a UK Centre for Economic and Environmental Development (UK CEED) research project into WEEE collection and treatment
- Wants to promote cost-efficient and innovative recycling strategies by embracing individual producer responsibility, thereby allowing waste disposal and management costs to become core business drivers. Developing and operating a common waste management procurement platform designed to meet the specific requirements of EEE producers
- Not keen on visible fees

In November 2004 the European Recycling Platform (ERP) established the first pan-European WEEE compliance scheme

Four leading manufacturers of electrical and electronic appliances, Braun, Electrolux, HP and Sony have today set up the first ever pan-European take back and compliance scheme for waste from electrical and electronic equipment (WEEE). To administer the pan-European scheme, the companies have today established the limited company ERP SAS, which is registered in Paris, France. The scheme, operating as the ERP WEEE Compliance Scheme, has been in development since December 2003 and is in response to the European WEEE Directive which is due to come into effect across Europe in the second half of 2005.

ERP will outsource all operational activities, including recycling, logistics and the administrative work to manage the operational activities to at least two general contractors. "ERP will take back WEEE from municipal and other collection points, such as retailers, in order to provide the best service for our customers and to ensure compliance for ERP Members." Korfmacher explains.

ERP WEEE Compliance Scheme will focus on operations in the following countries supported by two logistics companies appointed in December 2004 :-

CCR a European logistics company will be responsible for Austria, Germany, Italy and Poland

the French Geodis Group will be responsible for the UK, France, Spain, Portugal and Ireland

in February 2005 Sita and Geodis established a 50:50 joint venture to unite their European WEEE waste processing and recovery and logistics respectively : strategic project and operations management, logistics (including collection, consolidation and sorting, forwarding), processing and marketing.

These companies will manage all operational activities on behalf of ERP and its members : take-back, logistics and recycling. Both companies will be sub-contracting the treatment and transport of WEEE. Applications will be made for any necessary permits as and when the legislation and procedures become clear in each individual market. Additional countries will be considered at a later stage. Based on the four founders, ERP represents an estimated 15 percent of the pan-European WEEE take back market. Negotiations are taking place with a number of other companies interested in becoming ERP Members. Membership of ERP will be limited to avoid ERP establishing any dominant position.[3]

From August 13th 2005 ERP began its take-back and recycling operations across Austria, Ireland, Portugal and Spain. Awaiting relevant legislation to be finalised in France, Germany, Italy, Poland and the UK.

[3] www.erp-recycling.org

Recycling Electrical Producers Industry Consortium (REPIC), registered in December 2003 as a not-for-profit company. Covers all 10 WEEE categories.

- Initially = 12 manufacturers (Alba, Hoover Candy, Philips, Whirlpool, Sanyo, De'-Longhi/Kenwood, Panasonic, Hitachi, JVC, Smeg, Bose) = January 2004.
- Membership available to all firms defined as producers under the WEEE Directive and including manufacturers, import agents and retailers
- Each of the 12 companies committed themselves to £30,000 each towards the scheme's start-up costs, and each agreed to loan REPIC £20,000 for 2 years
- Also involves Association of Manufacturers of Domestic Equipment (AMDEA) and Intellect (another trade association) in the scheme development
- April 2004 = 36 companies, 70% of major appliance, small appliance and consumer electronics market. 80% by August 2005
- Pushing government in April 2004 to introduce a visible fee, or environmental charge, for customers to fund WEEE recycling, especially for equipment placed on the market before August 2005. This is allowed for in the Directive and covers products over 20 years old pre-August 2005 entering the waste stream, and will do so for next 20 years (i.e. historic/orphan WEEE).
- Accepting that producers will be financially responsible for recycling and treatment of equipment put on the market after August 2005.

In March 2005 REPIC warned that thousands of jobs in EEE manufacturing could move abroad unless the government passes the costs of the WEE Directive onto the consumer through a visible fee at time or purchase. Also demanded a 2006 start date for producer responsibility.

WEEE Forum

- a group comprising REPIC equivalents in other EU countries, has access to a wide network and knowledge base from schemes already in operation[4]
- contains detailed information on WEEE legislation in EU Member States, a detailed guidance document on compliance procedures and a collective take-back scheme
- at November 2005 30 compliance scheme members in 20 countries

European Electronics Recyclers Association (EERA)

- Announced in April 2004 as a European Trade Association - UK-based Sims group, MIREC BV, Stena Technoworld AB, Coolrec BV, Immark AG and R-plus GmBH
- Aiming for the harmonisation of national and international regulations for WEEE recycling. Taskforce preparing a policy paper concerning the rules for monitoring compliance with WEEE

July 2004, 3 non-European firms (Panasonic and JVC from Japan and Thomson from USA) announced their plans to set up a recycling scheme across Europe. Initially focussing on the German market, the intention is to establish a recycling scheme in each Member State when industry or sector-related collective schemes are not feasible or not cost effective.

Guidance published in October 2005 explaining how electronics producers can guide recyclers of WEEE : conditions for producers and treatment operators, regular contact to discuss past and future technology trends. Produced in association with European Digital Technology Industry, the household Appliance Manufacturers in Europe and the American Electronics Association Europe.[5]

The British Retail Consortium (BRC) 'Expressions of Interest to Provide Retail WEEE Compliance Scheme', January 2004. Government proposals suggest the retail compliance scheme provides at least £5 million annually 2005-10 to Local Authorities to upgrade civic amenity sites. The retail-led compliance scheme will have up to £5 million annually 2005-10. The British Retail Consortium, 21 Dartmouth Street (Second Floor), London, SW1H 9BP. Tel : 0207 854 8941. Fax : 0207 854 8901.

- in response to the second UK WEEE Consultation Paper, BRC supports the flexibility offered in providing retailers with the option of offering in-store takeback or compliance through a retail compliance scheme provided through a competitive bidding process
- in March 2005 the BRC estimated the cost to British retailers of WEEE to be possibly £10 million per annum, with retailers selling 'own-brand' items attracting both a producer and a retailer obligation. Also in March 2005, BRC announced that it was hoping to partner with a producer's compliance scheme.

---

[4] www.weee-forum.org
[5] www.eera-recyclers.com

- in June 2004 proposals put on hold until the government has clarified the operation of its proposed clearing house
- announced in September 2005 that Valpak will run the compliance scheme (to be called the Retail Compliance Scheme), working with 10,000 obligated businesses identified by BRC. Objectives include : collecting market share data across all categories, develop a model to reward existing take-back activities, establish a turnover threshold to levy a one-off fee to small businesses, create a customer information site. At January 2006 members include John Lewis, Dixons, Comet, Tesco, Woolworths, Acadia Group, Argios, B&Q, Boots, DSG International, Homebase, House of Fraser, MHI, Morrisons, Next, Somerfield, the Co-operative Group, Wickes Building Supplies. £80,000 provided in fees.
- Local Authorities will be able to bid for money from January 2006 to pay for upgrades to civic amenity sites
- With an adequate network of collection points in place, Dixons (part of DSG International) stated in October 2005 that "It will be waste of time training staff to take back WEEE in-store if no-one is going to use the scheme. The network of collection points will be there and it makes sense for retailers to use it".

At the Royal Society conference in March 2004 DTI and others announced that they were expecting to see re-use targets for WEEE in revisions to 2002 WEEE Directive. With increased amounts of WEEE being separated by businesses and householders this would benefit re-use organisations.

March 2004 Hewlett Packard against the mandatory 'visible fee' as an option to fund the recycling of existing WEEE, along with retailers and larger computer and IT manufacturers. Support for 'visible fee' comes from small household good manufacturers in the UK.

At APSWG meeting in March 2004:

- Environment Agency role : permitting of treatment facilities, regulating export of equipment/components/materials, registration of, producers (?), assessment of recycling rates, enforcement
- The Clearing House : initiated by the business community, number ? (one, few, many), functions (registration, logistics, promotion, a role in auditing compliance ?, 'penalties'), how will it be regulated ? To cover c. 25,000 'producers' (manufacturers and importers) covered by the Directive. Majority of support for a Clearing House : a telephone line arranging collection in fixed time, and could establish producers' share and calculate obligated tonnage.
- (the Clearing House concept has been driven by the 'Strategic Electronic Waste Policy Forum' – a small group of global manufacturers (Apple, Electrolux. Fujitsu, Hewlett Packard, Samsung Electronics, Gillette, Sony Computer Entertainment and Sony Corporation) working with the Associate Parliamentary Sustainable Waste Group established in October 2003.
- In June 2004 the DTI announced that the Clearing House (now being called the National Clearing House – NCH) will probably not feature in the draft regulations, although reference will be made to 'registration may be delegated to a third party'. NCH concept supported by the Environment Agency.
- Concerns of Environment Agency : no de minimis exemption for producers or retailers (unlike packaging), scope, registration of 'distance sellers' e.g. internet), clarification of role of regulators, funding (especially enforcement)
- Collection : Directive default requirement = in-store take-back, civic amenity sites, 'own-product' compliance or compliance scheme, retailer compliance scheme
- Treatment : storage, removal of fluids, selective treatment (see WEEE Directive, relevant extract reproduced in London ReMaDe report)

Both Local Authorities and retailers argue that access and size are problems in such options being proposed.

In May 2004, Defra published the long-awaited report Review of Environmental and Health Effects of Waste Management : Municipal Solid Waste and Similar Wastes. Although this included Materials Recovery facilities (MRFs), there is no mention of WEEE. At an Associate Parliamentary Sustainable Working Group meeting on 26th May 2004 one of the main authors (Professor R. Harrison) confirmed this, and also stated that the authors had not come across any other work on WEEE and health and the environment (but see reports listed earlier by Crowe et al and AEAT). It is likely that health and environmental impacts of WEEE will be covered in a Phase 2 study currently underway ?

Extended summary and main report: www.defra.gov.uk/environment/waste www.enviros.com

A report published in May 2004, commissioned by Royal Mail, estimated that 4% of new durable goods including consumer electrical items are returned to the retailer in the UK. Royal Mail has been interested in reverse logistics for 2-3 years, and is now working with US-base ReTurn Logistics to check electrical items that have been returned to its clients, refurbishing them for resale. A grading and refurbishment facility has been operating in Swindon for about 18 months. Some of the refurbished goods are being sold in on internet auction eBay.

In July 2004 the Environment Agency and SEPA published Guidance on Treatment of Waste Electrical and Electronic Equipment (WEEE). Consultation Draft. This covers health and safety issues, facilities, data collection and specific items to be removed.

In July 2004 Foresite Systems, a collaboration between Foresite and US-based GoodBye Chain Group, launched a compliance scheme for data collection and management of hazardous substances initially focussing on RoHS – see RoHS-WEEE.NET.

In August 2004 a new compliance scheme specifically to serve business-to-business and WEEE – GAMBICA B2B – by the trade association GAMBICA representing over 200 UK companies in the instrumentation, control, automation and laboratory technology industry. The focus will be on:

- IT and telecoms
- Medical devices
- Monitoring and control instruments

Covering such equipment as computers, freezers, laboratory equipment, radiotherapy equipment and smoke detectors. Some overlap with household WEEE where a company may give outdated computers to its staff for use at home.

July 2004 Comet and Curry's running pilot schemes for in-store take-back of WEEE, to evaluate if such schemes are worth establishing instead of, or in addition to the BRC proposals. They already operate a free collection service that pick up large appliances from households on delivery of a new item, although it is not clear if retailers will be able to charge a recycling fee for appliances collected in this way.

The Comet take-back scheme is operating for 3 months in 37 stores in the Birmingham area plus 11 Curry's stores, and is being run in partnership with Wincanton (logistics partner) and social enterprises CREATE, Renew and Remploy. Fridges are taken back by Wincanton to its 15 regional warehouses or 'platforms', 25% have been assessed as suitable for reuse (national average of 15%), and the rest are sent to Wincanton's fridge recycling plant in Billingham (with a capacity of 400,000 units a year).

In April 2005 Comet awarded a contract to logistics firm Wincanton to manage WEEE, having operated Comet's take-back service for fridges since 2003. Six regional centres will sort and grade WEEE received through Comet's home delivery service for re-use and/or recycling.

Wincantion launched its Revive national WEEE collection, treatment and recycling service during 2004 in partnership with Remploy, Sims metal recycling and Grundon waste management company. In August 2005 Wincanton announced that it had invested £4.5 million in a WEEE recycling plant in Middlesborough, able to process 75,000 tones per annum equating to 826,5000 washing machines or 67,000,000 kettles. The plant opened in February 2006, excluding cathode ray tubes and lighting equipment, the plant will take items from Local Authorities across the UK. Technology provided by German MeWa company – refurbishment, cross-cut grinder, separating components for refurbishment and sorting for recycling.

At the Transform WEEE conference in September 2004:

- Biffa argued for the WEEE allocation system to start in January 2006
- the National Clearing House must be established before the registration process begins
- whether retail stores are Designated Collection Points will depend on storage space and safety issues
- will retail delivery take-back count as 'in-store take back'?

Sims Group UK announced in September 2004 that it had created a new process for sorting and recycling mixed plastics from WEEE, using a density separation process that produces higher quality products with higher values. In October 2004 the company acquired the European WEEE recycler Mirec in order to expand its Recycling Solutions business, with its experience of asset management, take-back schemes and data capture.

In September 2004 Valpak, the packaging compliance scheme, announced that they intend to run a full 'pre-compliance service' for WEEE - £500 for companies with a turnover of £5 million or less and £1,000 for members with a turnover of over £5 million, with Valpak packaging compliance members entitled to a 25% discount. The service offers members information and advice about the WEEE Directive, a timetable of events and an overview of the various options for producers and retailers. The Press release indicated that Miele, Brother and Hornby plc had signed up. IN March 2005, Valpak announced an additional service (at an extra charge) to include product portfolio analysis, assessment of data audit requirements, estimates of compliance costs and a compliance impact assessment and preparation report.

Three community IT refurbishment groups in Yorkshire & Humber achieved ICER accreditation in September 2004 : Airedale Computer Recycling in Castleford, East Riding Training Services in Cottingham and Second Byte Ltd in Scunthorpe – all supported in gaining accreditation by Save Waste and prosper (SWAP) in Leeds.

In September 2004 Dell announced a new recycling programme, aiming to offer consumers an option for their WEEE as well as educating them. The take-back scheme is offered to customers when purchasing new equipment from Dell (for both Dell and other WEEE), and also those people not wishing to purchase anything, involving free collections from home. Dell will also offer a donation service in association with the National Cristina Foundation. For businesses the company is offering Dell Asset Recovery Services (ARS), where business customers can recycle or re-sell redundant computer equipment. Customers will also be able to donate old PCs to ReCOM, a charity that distributes IT equipment to charities and community groups in the West Midlands.

A report from the Chartered Institute of Logistics and Transport published in October 2004 indicated that the cost of returns of WEEE items to retailers was costing £500 million per annum, a situation complicated by internet and hole shopping sales an companies fearful of losing customers if they don’t take back such items.

In November 2004, IBM expanded its Asset Recovery Solutions (ARS) scheme to the UK. The ARS programme offers companies the chance to sell their old kit to IBM at 'current market values'. The offer extends not only to old IBM hardware but equipment from other manufacturers too. For large amounts of redundant kit, IBM will pack it up, take it away and overwrite data on the hard disk before selling the products on or disposing of them.

Following the European WEEE (Waste Electrical and Electronic Equipment) Directive, British businesses are now required to reuse and recycle their redundant electrical equipment rather than dump it in landfill.

The ARS scheme provides the customer with a single up-front cash payment paid in 30 days. Companies who reckon their old kit is worth more, however, can put it up for auction instead with IBM taking a cut of the final selling price.

In November 2004 Onyx launched a new collection and recycling service for WEEE in partnership with Leeds-based electronics recycling specialist Silver Lining Ltd., and is being offered to any commercial generator of WEEE in the UK or Ireland. Key to the new service is the ability to use the Onyx web site or a new telephone hotline to request collections. Two services are being offered : a ‘Box and Go’ service for large WEEE items and a ‘Tubecare’ service for fluorescent lighting tubes and lamps with Onyx delivering the required waste containers, collecting when requested for sorting at the company’s Leeds sorting centre before materials are sent for recycling to Silver Lining Ltd.

Low-cost packaging compliance scheme Budget Pack launched a pre-compliance scheme for WEEE in December 2004 called the Entry Scheme.

Waste services company Wastelink Group launched a WEEE compliance scheme in November 2004, called Electrolink. The company operates Wastepack for packaging compliance. With c. 100 of its existing members producing WEEE, the scheme offers a ‘pre-compliance’ service for such companies free of charge, and to other WEEE producers at a charge of £295 per year.

In January 2005, community group SOFA (Suppliers of Furniture and Appliances) Leicestershire is in the process of setting up a new centre where it expects to take nearly 500 waste appliances, such as fridges and cookers, a month. The service will initially serve households in the Blaby district council area, but will widen its activities to cover other Local Authorities in the county.

The target to take in 475 waste electrical goods a month by May 2005 has been set by CRED (Community Recycling and Economic Development), which has given the organisation £70,000 over a three year period, towards the expansion. The Environment Agency has provided a grant of £10,000.

Previously, only items in very good condition were accepted but the new service will take goods in poorer condition and will pass on any item that can't be reworked to a reprocessor. They are expecting to be able to reuse about 40% of the goods at first but this might drop to around 25% as we become less discriminatory. SOFA was currently working with a metal reprocessor, but it was likely the group would be looking for other reprocessors in various sectors in the future.

Report in March 2005 that Furniture Reuse Network (FRN) members are establishing a network of 35 regional consolidation centres, offering a full audit trail and a national standard for appliance reuse and recycling. RFIDs are to be used to record data at point of collection (e.g. civic amenity sites), with pilot scheme now being updated.

Yorkshire-based Electrical Recycling Company (ERC) is a partnership between waste management company Yorwaste and consumer electronics experts DBS York Ltd, and in May 2005 wants to collect TVs for recycling direct from retailers. They have developed a system for recycling of CRTs, at up to 55 per hour. July 2005 offering a national collection service for TVs to be disassembled at the plant near York, with markets for over 90% of the recycled material.

Two WEEE compliance schemes (B2B Compliance – an initiative of the GAMBICA trade association for scientific equipment and Lumicom – Lighting Industry Federation) joined forces in June 2005 to search for a company to provide logistics and recycling facilities.

In late July 2005 the Singapore-based parent company of Citiraya UK faced possible legal action. However, the CRT recycling plant at Hirwaun in South Wales will not be affected – although the Irvine plant in Scotland closed earlier in July. This acted as a transfer station, sending CRTs to Singapore and more recently South Wales. TES-AMM (a rival of Citiraya in Asia) acquired the Scottish plant in September 2005, with metals and cardboard being sold in local markets, CRTs being sent to Malaysia, and all WEEE (in Scotland, China, Malaysia, Hong Kong, Singapore and Thailand) being electronically tracked using Cygnet Solutions.

A new CRT recycling plant in Preston is due to open by the end of 2005, operated by computer-recycling.co.uk (part of Recycling.co.uk).

Revision Glass, Ross on Wye, is involved with CRT glass recycling.

The Environcom plant in Grantham started up in June 2004 and added a second CRT recycling line in November 2005, with a combined capacity of 400,000 televisions and monitors per month. The plant uses Danish MRT Systems technology and Lindemann shredders.

It is estimated that c. 100 million light bulbs are discarded in the UK each year, with c. 18 million being recycled in 2005. East Anglia-base Recyclite won a contract in September 2005 to reprocess all the lamps collected by Weblight (clients include BHS, Marks and Spencer and Tesco), a total of c. 40 million lamps per annum. Mercury in Manchester moved into a new site in November 2005 and will be able to process 10 million lamps a year by the end of 2005 with a second recycling line, with its own equipment replacing MRT Systems, and eventually 40 million lamps a year. The company had a 1% market share in 2003 and now has 10%, with capacity to collect from every postcode in the UK, and recovers ferrous and non-ferrous metals, glass, mercury-bearing phosphor powder, plastics and sodium.

The big four light producers (Ozram, General Electric, Philips and Sylvania) have joined to form their own compliance group, Rekolight. With a visible fee of 35p for each lamp this would raise £3 million.

In August 2005 REPIC and B2B Compliance announced that they will be working together when producer responsibility finally begins.

Various reports in summer 2005 suggest that metal re-processing companies are forging multinational partnerships in order not only to process WEEE but a range of other recyclable materials (metals, plastics, glass) and hazardous wastes. UK-based Sims Group has links with Sweden, acquired European Mirec Group in 2004 (recycles CRTs) and US Hugo Neu in 2005,and has a logistics plant in the Netherlands.

RABBITT (Recycle All Batteries, Bulbs, Inkjets, Toners and Telephones) Recycling, based in Gloucestershire was established in 2003 and works with a range of companies using a large database of companies who will process all sorts of waste materials – 20 being handled at August 2005. Includes both UK and export markets, with future developments potentially including franchising the concept into the marketplace.

In September 2005 The Waste Electrical Electronic Equipment Directory launched a free on-line tenders and conditions service. Companies can list its WEEE and the directory then matches the details to listed recyclers, who will send a quote.[6]

In March 2006 Brother announced that it had produced a component from recycled polystyrene.

www.PRW.com reported that printer and fax manufacturer Brother and Axion Recycling had produced a trial internal fax machine component using plastic from waste electrical and electronic equipment (WEEE).

For the trial, an internal fax machine component, produced at Brother's Ruabon plant in North Wales, was chosen because the company already had a specification for this part to be made from recycled polymer.

Key to the project was an effective sorting system, as two tonnes of shredded WEEE plastics was used. This was subjected to a range of cleaning and separation processes to produce around 800 kg of sorted,
single polymer material. An impact modifier was added and a 100 kg sample of black "on specification" polystyrene pellets was delivered for Brother's injection moulding trial.

Neil Lloyd-Richards, technical manager of Brother subsidiary GKK, said: "This trial proves that the sorting and recycling of WEEE plastic waste can give a viable high quality polymer which can be used to produce high quality high specification components."

[6] www.weeedirectory.com

With funding in place in January 2005, £194,263 from Biffa + £194.263 from CRED = £104,000 from HMPS, Goods Again was established involving HMP Olney, Warwickshire Environmental Trust, local charity Coventry City Mission and Warwickshire County Council. Operations began in September 2005. Items are checked, refurbished where possible and components stripped down for donor parts. So far, collections are the main problem, but the prisoners benefit from specific skills and associated literacy and numeracy

Further WEEE Consultation – July 2006

Another WEEE Consultation was published in late July 2006, seeking views of businesses, manufacturers, retailers, producers and enforcement authorities on draft regulations implementing Directives 2002/96/EC and 2003/108/EC of the European Parliament relating to waste electrical and electronic equipment. This consultation does not seek views on the provisions of the Directive itself but on the UK's proposed interpretation of it.[7]

The consultation marks the beginning of the final phase of the Government's process for implementing the WEEE Directive. The proposals outlined in the consultation follow on from a review of our implementation proposals last December and have been developed through extensive consultation with key stakeholders to ensure that they are workable.

The key proposals are:

- a national Distributor Takeback Scheme which will establish a network of Designated Collection Facilities enabling consumers to return their used items for recycling or reuse
- obligatory registration for producers through approved compliance schemes Authorised Treatment Facilities, which will process WEEE and provide evidence to producers on the amount of WEEE received for treatment
- accredited reprocessing/recycling facilities who will provide evidence of reprocessing to producers
- an end-of-year settlement to ensure producers are able to meet their obligations via an "Exchange" system
- a voluntary approach for producers to show the cost of handling historical WEEE.
- implementation with effect from 1st July 2007

The consultation will run from 25 July until 17 October 2006.

The WEEE Directive aims to address the environmental impact of electrical and electronic equipment (EEE) and to promote its separate collection when it becomes waste (WEEE). WEEE is a priority waste stream for the EU because of its growing volume in the municipal waste stream and its potential hazardousness following disposal.

The Directive introduces producer responsibility for waste electrical and electronic equipment (WEEE). Producers will have to finance treatment and recycling/recovery of separately collected WEEE in the UK to specified treatment standards and recycling/recovery targets. Retailers have an obligation to offer take-back services to householders. The Directive does not place any obligations on householders, and they will be not be prohibited from throwing WEEE away with general domestic rubbish. It will however encourage more WEEE to be reused or recycled by ensuring that there is a network of facilities in place where householders can return their used equipment free of charge.

Additional regulations - WEEE Permitting regulations - are to be made by Defra, together with guidance on treatment operations. The Regulations will come into force alongside the producer responsibility requirements of the DTI WEEE regulations and will introduce the treatment permitting requirements of the WEEE Directive.

Results from a monthly evaluation report are available online.

IT Week reports (end-July 2006) that the proposals are likely to face continued opposition from some equipment makers. The DTI has admitted that an early regulatory impact assessment revealed the new law could cost manufacturers up to £500m a year, much of which would be passed onto customers in the form of higher prices.

Interested parties now have until the 17th October 2006 to provide feedback on the draft implementation plan and regulatory impact assessment. Energy minister Malcolm Wicks said the government had been right to delay the implementation of the directive - despite the threat of legal action from the European Union - claiming the postponement had provided time to develop workable proposals. He argued that many countries that implemented the directive on time were now facing difficulties with the scheme.

[7] WEEE consultation: Part I. Draft implementation of directives 2002/96/EC and 203/108/EC on waste electrical and electronic equipment
http://reporting.dti.gov.uk/cgi-bin/rr.cgi/http://www.dti.gov.uk/files/file32449.pdf

Under the current proposals a national network of WEEE collection, recycling and disposal facilities will be set up, equipment producers will then have to register with approved compliance schemes and contribute to the cost of collection, recycling and disposal in proportion with their market share. For example, a company with 20 percent market share will have to pay 20 percent of the cost of handling the waste equipment. IT directors will see little direct impact as a result of the legislation, according to Deborah Huntington at the DTI, as suppliers will be responsible for collecting the old equipment they replace when delivering new products. Products being disposed of without a replacement will have to be dealt with by firms in accordance with existing waste regulations included in the Environment Act, she said. However, some experts believe the new directive will impact customers in the form of significantly higher IT hardware prices as producers pass on the cost of compliance to customers. One report from analyst firm Gartner has claimed the legislation could add as much as $60 to the price of a computer.

Huntington admitted early regulatory impact assessments from the DTI had concluded WEEE could cost UK industry up to £500m a year. Under the current proposals, suppliers will be free to decide whether to pass the cost onto customers and will also be able to decide whether to make the cost of compliance a visible add-on to price tags - effectively a WEEE tax - as has been the case in Ireland or absorb it into current prices. Wicks said it was up to firms how they handled the cost of compliance, but argued that more responsible firms would not adopt visible pricing. He also claimed that ultimately any cost passed onto customers will be eroded as the legislation "will influence manufacturing standards and R&D [to make it easier to recycle products cost effectively]".

Local Authority Involvement

February 2004 London councils face a £2 million to upgrade civic amenity sites to help deal with 170,000 tonnes of WEEE : £80,000 for large sites, £30,000 for bins at small sites. Labour and collection costs could add up to £20,000 of this total. (see report by London Remade).

In May 2004 Defra published its Reply to the House of Commons EFRA report on ELV and WEEE. This included reference to a 'hierarchy' of collection schemes for WEEE :-

- 'The Government is keen to build on existing infrastructure where possible, and agrees that civic amenity sites have an important role to play in the separate collection of WEEE'. (The EFRA report recommended that 'the current network of civic amenity sites be expanded, so that such sites are easily accessible to all', while existing sites be developed). Local Authority and the LGA reaction is that they do not feel they should be burdened with collecting WEEE on behalf of manufacturers and retailers, whilst retailers feel that Local Authorities are best placed to help with collection.
-
- 'However, the Government recognises that the WEEE Directive does not place obligations on Local Authorities and, therefore, the Government will not place any new un-financed burdens on local authorities'. '... local authorities would be able to bid for money to upgrade their civic amenity site infrastructure to separately collect WEEE'.
-
- 'In order for collection points to be easily accessible for consumers, the proposals also suggest that in addition to separate collection facilities at civic amenity sites, there should be a number of retailer run collection points at, for example, retail parks'. Some mobile phone shops already operate such schemes, and LARAC argue that retailers are best place to take advantage of reverse-chain logistic efficiencies – especially for smaller items. The British Retail Consortium are developing an alternative plan, probably based on existing (Local Authority) collection systems and cite the need for Environment Agency licensing of 322,000 retail outlets in the UK.
- 'Where this is not possible, alternative arrangements should be put into place, such as organised bring events or kerbside collections of WEEE'.
- 'In the case of larger appliances, the continuation of take back on delivery of new equipment is encouraged'.

A pilot resource recovery facility was opened by Onyx (in conjunction with Hampshire County Council) in Portsmouth in July 2005, with the aim of recycling 3,000 tonnes of WEEE. The facility aims to compare the technology and economics of dismantling and redistributing WEEE in accordance with the Directive. An online tracking system is planned, which will allow manufacturers of products designed for material recovery to re-source their materials. Onyx Environmental Trust provided £579,091.

The London Borough of Bexley have worked with EMR to establish 20 banks for small WEEE items. 74% of WEEE items entering the 2 civic amenity sites were large household appliances. London ReMade provided £16,000 for the 20 banks plus £5,500 for a reuse container at its 2 civic amenity sites.

March 2006 a research project suggested that regular kerbside collections of WEEE are a possibility, in order to prevent contamination with other waste. Funded by Onyx, the project modelled WEEE from households in Hampshire based on socio-demographic data, how many EEE items are expected to be owned by the household, the expected weight of each item and the expected replacement time. Costs were also assessed, and the potential role of HWRCs. A similar modelling exercise is being carried for the Local Authorities within the M25.

A recycling event in March 2006, involving Hewlett Packard and Valpak, to offer residents in Lambeth the opportunity to return WEEE free of charge at the local HWRC. Trial in association with Recycle Western Riverside, London Remade, the council and electronics re-processor Technowaste (based in Basildon).

In April 2006 Express Recycling and Plastics Ltd announced that it will take plastics from WEEE, in addition to other rigid plastics, with a second line starting in September 2006. The plant uses Dutch technology from company Envirotech, with a capacity of 60,000 tonnes per annum, having received a £75,000 grant from the London Recycling Fund.

Appendix 2 – Material test results from London Metropolitan University for WEEE polymers

Report on results from testing of mechanically separated plastic samples and product from Phase 2 technical scale Creasolv process trial

Report No. KH-PC 1981/05

Processing, Testing and Analysis of WEEE material

Prepared for: Axion Recycling Ltd

For the attention of: Keith Freegard
Roger Morton

Reported by: Peter Cracknell
Karina Hernandez
Polymer Centre
London Metropolitan University

Date: 16th August 2005

1. INTRODUCTION

At the request of Axion Recycling (UK) Ltd, various tests were carried out on samples of WEEE materials supplied by the company to compare the properties of each sample with the actual commercial ranges. The whole procedure was carried out in LMPC (London Metropolitan Polymer Centre) laboratories.

2. SAMPLES

The materials were provided by Axion Recycling Ltd and were mainly obtained from IT samples (HIPS, PS, ABS, ABS/PC), telephones (ABS), TV cases (HIPS), washing machines (ABS, PP) and bulk materials (ABS/PS). One sample came from trials by Fraunhofer IVV of the Creasolv process on TV casings.

Reference numbers were assigned to the samples in accordance to polymer type and its source:

Reference Number	Polymer	Notes/Description
AXION001	HIPS	IT SAMPLES
AXION002	ABS/PC	IT SAMPLES
AXION004	PS	IT SAMPLES
AXION006	ABS	TELEPHONES (GRANULATED)
AXION007	HIPS	TV CASES (GRANULATED)
AXION008	ABS	WASHING MACHINES
AXION009	PP	WASHING MACHINES
AXION010	ABS	IT SAMPLES (GRANULATED)
AXION011	ABS/PS	PHB BULK MATERIALS SAMPLES
GERM001	HIPS	Creasolv BROMINE EXTRACTED

The materials were extruded after being reduced in size and granulated. The following pictures show their appearance at these two stages.

AXION 001 HIPS (IT Samples)

Before **Extruded**

AXION 002 ABS/PC (IT Samples)

Before **Extruded**

AXION 004 PS (IT Samples)

Before **Extruded**

AXION 006 ABS (Telephones)

Before **Extruded**

AXION 007 HIPS (TV Cases)

Before **Extruded**

AXION 008 ABS (Washing machines)

Before **Extruded**

AXION 009 PP (Washing machines)

Before **Extruded**

AXION 010 ABS (IT Samples)

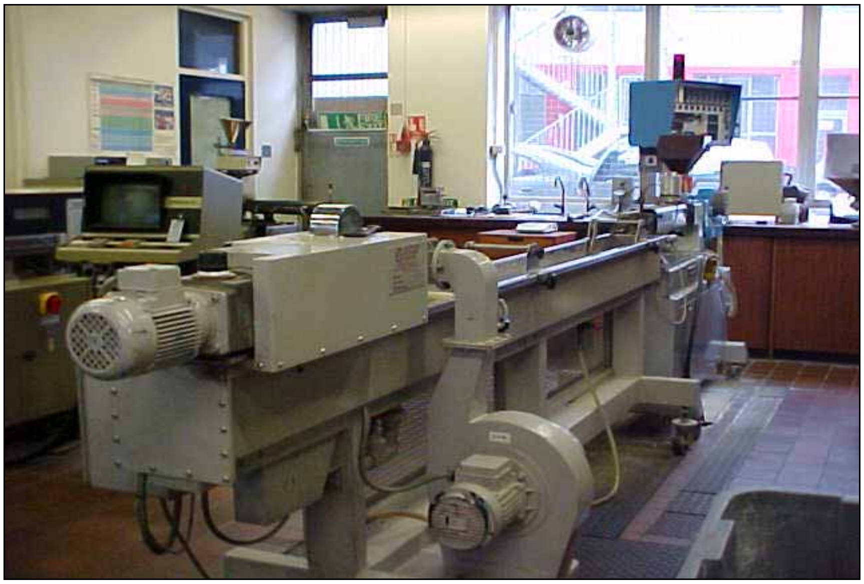
Before **Extruded**

AXION 011 ABS-PS (PHB BULK materials Samples)

Before **Extruded**

3. EXTRUSION PROCESS

The extrusion process was carried out on a Twin screws extruder. Micro18, Leistritz.
Screw diameter: 18 mm; centre distance: 15 mm; operating length of screws: 7 R.
Main drive motor: DC-shunt wound motor
Drive power: 2.2 kW



Twin screw extruder

Extrusion settings

The settings established were as follows:

Polymer reference number	Polymer	Drying Time, hr	Drying Temperatures °C	Temperatures Settings °C	Feeder Speed	Pellet Speed	Melt Point °C	Torque %
AXION001	HIPS	--	NA	185-240	10	8	240	60
AXION002	ABS/PC	4	70	220-265	7	6	258	60
AXION004	PS	3	70	215-240	10	8	235	65
AXION006	ABS	3	80	200-255	10	9.5	225	50
AXION007	HIPS	--	NA	185-240	10	7	233	70
AXION008[8]	ABS	3	80	220-270	3	4	240	35
AXION009	PP	3	85	220-240	10	9	226	65
AXION010	ABS	3	80	200-255	6	7	223	60
AXION011	ABS/PS	3	80	215-245	10	8.5	220	55
HIPS GER	HIPS	2	65	195-235	10	7	228	60

[8] Material ref. AXION 008 presented some problems when extruded, It was due to the presence of metal in some of the sample.

Most of materials required being dry before extruded due to moisture absorption; particularly GERM001, which had been through the Creasolv Bromine extraction process and could have absorbed some moisture. The extrusion temperatures were set following commercial standards. They were adjusted where required. Feeder and pellet speed were adapted during processing; torque and melt point were identified while processing.

4. INJECTION MOULDING PROCESS

As in extrusion process, some materials required to be dry before injection moulding, the same drying conditions were used for both processes.
After being dry, the materials were processed in an Injection moulding machine, ref. Klockner Ferromatic F60.
Pump drive: 12 kW
Total connected power: 23.3 kW
Length: 3,6, width: 1,2.

Injection Moulding Machine

The settings for this process were the same for all materials in order to compare them effectively, and these were as follow:

Polymer	**Mould Temperature °C**	**Barrel Rear Temperature °C**	**Barrel Middle Temperature °C**	**Barrel Front Temperature °C**	**Nozzle Temperature °C**	**Cooling time Sec**
ABS	60	215	230	230	235	10
ABS/PC	60	215	230	230	235	10
ABS/PS	60	215	230	230	235	10
HIPS	60	215	230	230	235	10
PS	60	215	230	230	235	10
PP	60	215	230	230	235	10

5. TEST DESCRIPTION

In order to find out the mechanical and thermal properties of all materials and compare them to commercial ranges the following testing plan was established:

Izod Impact

This test is a high-speed flexural test. It measures the energy to break a specimen by swinging a loaded pendulum from a fixed drop height so that the striker hits the specimen at a fixed speed and with a given energy. It measures the energy removed from the swinging pendulum by the impact and this energy is assumed to be the energy used to break the specimen, the higher the energy the tougher the material.

Tensile Strength

A dumbbell shaped test piece is continuously pulled apart by means of an extensometer and the force and elongation are measured by use of a chart recorder until the fracture occurs. From this, stress and strain can be read from the graph and use to calculate the tensile strength of the material, which is the maximum force required to pull a sample of the material apart. The response of a material to applied stress may be described as "Ductile" or "Brittle," depending on the extent to which the material undergoes plastic deformation before failure. There are some characteristics of the curve strain-stress to observe:

- The larger the tensile strength, the stronger the polymer
- The smaller the are under the curve stress-strain, the more brittle the material, it can be deduced as well when the polymer does not have yield point.

HDT(Heat deflection temperature)

This kind of testing is made to determine at which temperature plastics materials begin to soften. It is important as this indicates the maximum temperature that a sample can endure short term without significant deformation.

The test consists of supporting a rectangular bar over a span of 100mm and loading it with a central stress of either 1.82 or 0.44 Mpa. Heating is supply by immersion in an oil bath and then the heating rate is normally 1200 C/hour. The HDT value is taken to be the temperature at which a deflection of 0.25mm is observed.

Rheological analysis

This test is performed to study the behaviour of the flow of each of the materials being a quality control test. The equipment employed this time was a Capillary Rheometer, which measures apparent viscosity over an entire range of shear stresses and shear rates encountered in compression moulding, extrusion, injection moulding operations.

The temperatures, pressures, shear rate force are pre-established, then the sample runs all the way through the die giving the results. A chart shear viscosity vs. shear rate is obtained. A good material's processing is shown when the shear viscosity decreases while the shear rate increases.

Spiral flow

Flow properties can be measured using transfer moulding into a spiral flow tool. The moulding temperature, transfer pressure, charge mass, press cure time, and transfer plunged speed are pre-selected as specified. The material is forced through the machine into a spiral flow mould. Once the process is finished the piece is removed and the spiral flow length is read directly from the moulded specimen, the larger the value the higher the plasticity.

6. TEST PROCEDURES AND RESULTS

6.1 IZOD IMPACT TEST (UNNOTCHED AND NOTCHED SAMPLES)

It was measured referring to the ISO 180 : 1993(E) " Determination of Izod impact strength" and performed on a Universal Pendulum Impact System for Izod-Charpy- Tension and Puncture.

Velocity of impact 5.5 J, Hammer weight of 0.898 Kg.

POLYMER	COMPOUND	IZOD IMPACT (KJ/m^2)	COMMERCIAL RANGES IZOD IMPACT (KJ/m^2)
HIPS	AXION001 (UNNOTCHED) NOTCHED	***(65.40)*** ***7.98***	5.33 -11.99
ABS/PC	AXION002 (UNNOTCHED) NOTCHED	***(89.40)*** ***9.04***	68.60-69.93
PS	AXION004 (UNNOTCHED) NOTCHED	***(30.42)*** ***5.66***	General purpose 1.33-2.66 Medium impact 3.33-4.66
ABS	AXION006 (UNNOTCHED) NOTCHED	***(42.02)*** ***10.52***	Low T impact 39.96-66.60 Medium T impact 13.32-26.4 High T impact 33.30-46.62 Heat resistance 13.32-26.64
HIPS	AXION007 (UNNOTCHED) NOTCHED	***(45.34)*** ***3.26***	5.33 –11.99
ABS	AXION008 (UNNOTCHED) NOTCHED	***(33.01)*** ***7.85***	Low T impact 39.96-66.60 Medium T impact 13.32-26.4 High T impact 33.30-46.62 Heat resistance 13.32-26.64
PP	AXION009 (UNNOTCHED) NOTCHED	***(16.70)*** ***2.59***	General purpose 2.66-14.65 High impact 9.99-79.92 Flame retardant 14.65
ABS	AXION010 (UNNOTCHED) NOTCHED	***(4.87)*** ***2.40***	Low T impact 39.96-66.60 Medium T impact 13.32-26.4 High T impact 33.30-46.62 Heat resistance 13.32-26.64
ABS/PS	AXION011 (UNNOTCHED) NOTCHED	***(25.37)*** ***7.40***	
HIPS	HIPS GER (UNNOTCHED) NOTCHED	***(7.88)*** ***2.88***	5.33 –11.99

6.2 HDT TEST

It was measured using HDT/ VICAT softening Point Apparatus (RAY-RAN) in accordance with **ISO 75-2 : 1993. Method Af**[9] **"** Determination of temperature of deflection under load."

POLYMER	*POLYMER* **REFERENCE NUMBER**	**TEMPERATURE AT DEFLECTION °C**	COMMERCIAL RANGES TEMPERATURE AT DEFLECTION °C
HIPS	AXION001	75.93	99
ABS/PC	AXION002	84.08	104 –122
PS	AXION004	84.13	General purpose 104 max Medium impact 99 max
ABS	AXION006	82.23	Low T impact 85 - 107 Medium T impact 85 - 106 High T impact 82 - 103 Heat resistance 104 - 118
HIPS	AXION007	78.55	99
ABS	AXION008	81.88	Low T impact 85 - 107 Medium T impact 85 - 106 High T impact 82 - 103 Heat resistance 104 - 118
PP	AXION009	102.33	General purpose 57 - 60 High impact 49 - 60 Flame retardant 68
ABS	AXION010	78.13	Low T impact 85 - 107 Medium T impact 85 - 106 High T impact 82 - 103 Heat resistance 104 - 118
ABS/PS	AXION011	80.05	99 – 116
HIPS	GERM001	75.35	99

The values obtained are comparable to commercial ranges of values; most of the materials have an appropriate deflection temperature.

[9] 1.8 Mpa and Flatwise

6.3 SPIRAL FLOW TEST

The moulding settings used were exactly the same for all materials specified in the injection moulding section. Materials are classified as:

Low plasticity: 1-10
Medium plasticity: 11-22
High plasticity: 23-40

The higher the plasticity the better flow behaviour the material has.

The measurements were done following **ASTM D 3123** standard "Spiral flow mold for plastics".

POLYMER	*POLYMER* **REFERENCE NUMBER**	**PLASTICITY (Flow behaviour)**		
		Low	**Medium**	**High**
HIPS	AXION001		21.55	
ABS/PC	AXION002		16.94	
PS	AXION004			22.56
ABS	AXION006		17.15	
HIPS	AXION007			24.31
ABS	AXION008		16.44	
PP	AXION009			23.44
ABS	AXION010		20.38	
ABS/PS	AXION011		21.96	
HIPS	GERM001		19.2	

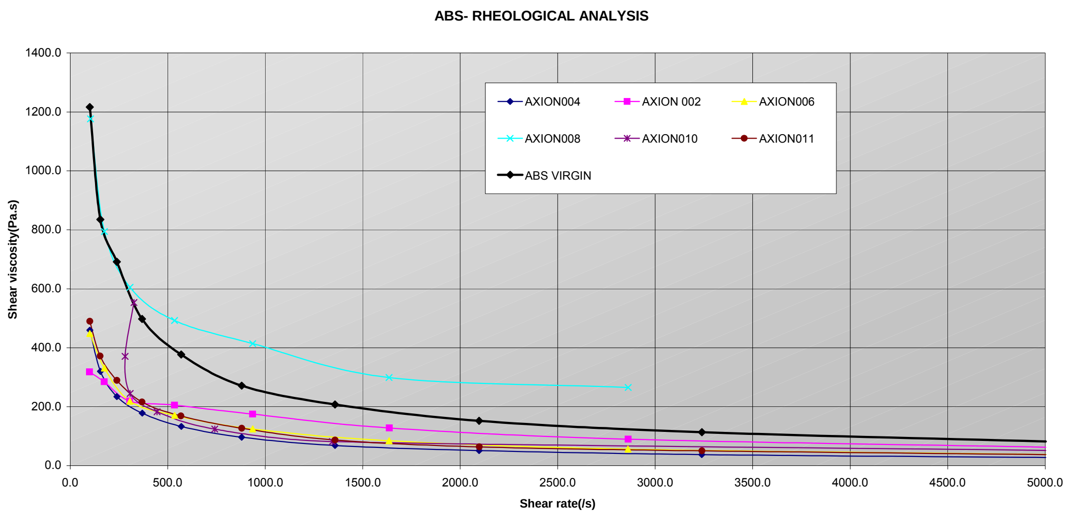
6.4 TENSILE STRESS-STRAIN

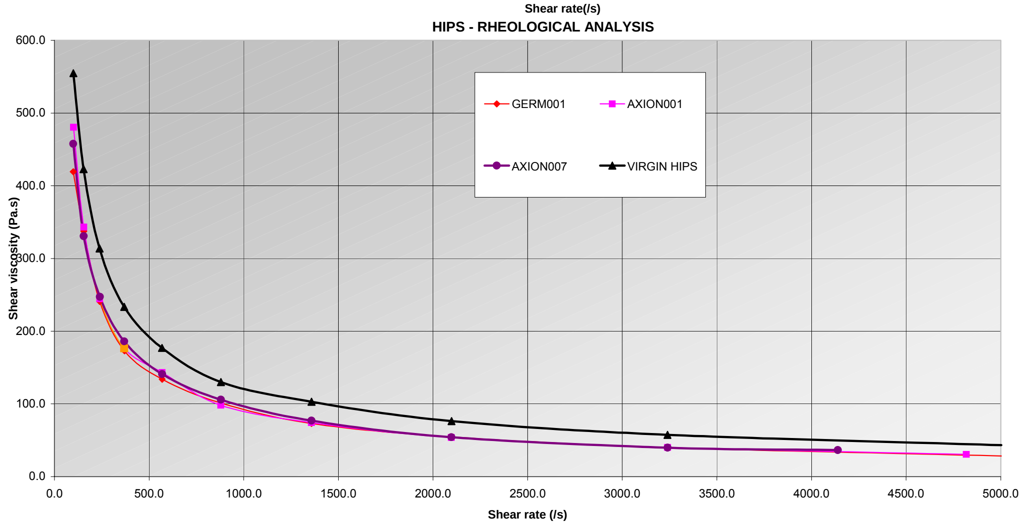
This test was carried out on INSTRON 1122, adding a 5KN cell load, speed of 50 mm/min and grip separation of 110 mm. The standard followed was **ISO 527 (BS 2782- 3), Method 320 C** " Tensile Strength, elongation and modulus."

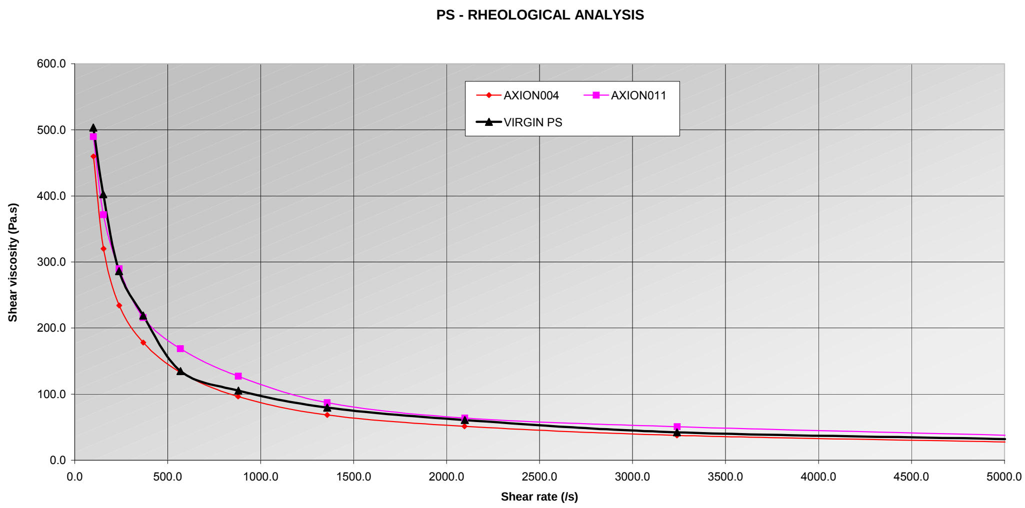
Polymer	Polymer Reference number	Tensile strength at yield (Mpa)	Tensile strength at break (MPa)	Elongation at break, %	Commercial ranges Tensile strength at yield (MPa)		Commercial ranges Elongation at break, %
HIPS	AXION001	24.35	20.10	23.42	General	19.29 to 36.51	30 – 40
ABS/PC	AXION002	58.0	50.8	13.0	General	31 - to 52	___
PS	AXION004	31.4	25.1	17.5	General purpose	32.4 to 68	1.2 to 2.3
					Medium impact	41.34	3 – 40
ABS	AXION006	45.68	37.50	12.25	Temperature impact, Low	27.56 to 41.34	30-200
					Medium	43.47 to 55.12	5-20
					High	31 to 41.34	20-50
					Heat resistance	48.23 to 55.12	20
HIPS	AXION007	25.8	22.1	29.1	General	19.29 to 36.51	30 – 40
ABS	AXION008	43.50	38.55	12.98	Temperature impact, Low	27.56 to 41.34	30-200
					Medium	43.47 to 55.12	5-20
					High	31 to 41.34	20-50
					Heat resistance	48.23 to 55.12	20
PP	AXION009	38.6	36.6	6.1	General purpose	33 to 38	30-200
					High impact	19.29 to 30	30-200
					Flame retardant	41,34 to 68.9	3-15
ABS	AXION010	BRITTLE	36.4	11.6	Temperature impact, Low	27.56 to 41.34	30-200
					Medium	43.47 to 55.12	5-20
					High	31 to 41.34	20-50
					Heat resistance	48.23 to 55.12	20
ABS/PS	AXION011	31.7	27.9	15.5			
HIPS	GERM001	BRITTLE	34.0	4.0	General	19.29 to 36.51	30 – 40

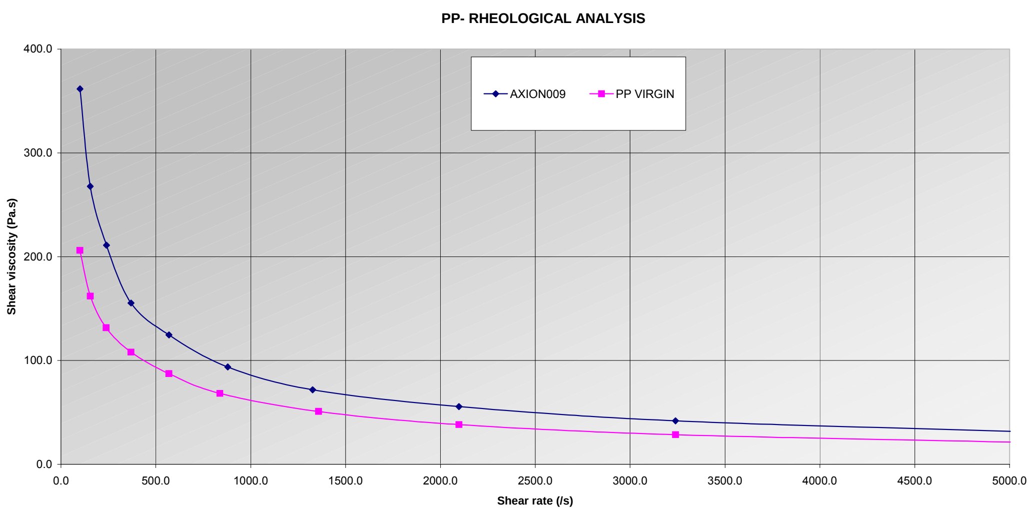
6.5 RHEOLOGICAL ANALYSIS

The test was performed in a ROSAND Capillary Rheometer RH2000, following the **ISO 11443** standard "Shear Viscosity: Plastics - Determination of the Fluidity of Plastics Using Capillary Rheometer (**Method A**)."
The curves shear rate Vs shear viscosity were obtained and also compared with virgin material keep in the workshop of Polymer Centre (LondonMet).









The materials all have good profile match, giving evidence of a good Mw range therefore indicating low degradation of the material.
Although, the samples lower profile than the virgin material, they are in a range that allows comparison between them.

6.6 Melt Flow Index (MFI)

This test was prepared under the direction of the standard **ISO 1133 Method 720A** “Determination of melt flow rate of thermoplastics.” Measurements were made using a RAY-RAN Melt flow Tester.
The result obtained was:

Material reference number	Polymer	MFI (gr/10min)
Axion011	ABS/PS	7.41

This value inferred that the material is potentially versatile in extrusion and injection moulding processing.

8. GENERAL COMMENTS

The test specimens which exhibited the lowest impact test results (Axion 010 ABS) showed no serious decline in HDT, Tensile or Rheological properties; one explanation which would explain this behaviour is that those specimens were contaminated with foreign matter e.g. wood particles. Such contamination would set up crack propagation sites resuming in a reduction in Impact strength without seriously affecting the other tested properties which are within reasonable limits. This characteristic is common with regard to ABS in particular.

Izod Impact Test
Results show nothing unexpected for most material grades apart from Axion010 (ABS) specimens, which are on the low side.

HDT, Tensile and Rheological Testing
All results are within reasonable expectation for the tested materials and show no significant difference to expectation.

Additives in Recycled material

Plastics are organic materials and are therefore subject to natural ageing from the influence of temperature, air, light and weathering. The shearing forces of a processing machine, together with the high temperatures and the residual oxygen already, cause preliminary molecular damage, such a chain cleavage, crosslinking or the formation of double bonds. This ageing process goes along with impairment in the visual and mechanical properties of the plastic and applies to both virgin and recycled materials. An additional difficulty with WEEE plastics is the degree of molecular damage caused during the original application. To inhibit those degradation reactions, or at least to slow them down, additives may be added to plastics. These additives include fillers, pigments, flame retardants, plasticizers and modifiers.

These additives contribute conserving sources by extending the lifetime of plastics and through optimum stabilisation, the amount of plastic can in many cases be used more efficiently and more economically, leading to thinner-walled articles.

In impact modified PS and in ABS, the polybutadiene component is much more sensitive to oxidation than other polymers.

In ABS especially loss of impact strength is associated with the oxidation of the polybutadiene phase. This oxidation leads to cross-linked and reduction of its elasticity because polybutadiene is slightly cross-linked on purpose during manufacturing, oxidation leads to over cross-linking and, as a consequence, deterioration of the mechanical properties of ABS therefore an antioxidant would help to improve its properties.

Ageing stabilizers (Antioxidants) can interrupt the oxidation mechanism at high temperatures. They are effective at concentrations of a fraction of one percent.

Report on testing of final products from large scale Creasolv and Centrevap process trials in Phase 3

Melt Flow Rate, Heat Deflection Temperature, Tensile and Impact Strength Analysis

Recycled HIPS Samples

Report No. 2037

Client: **Axion Recycling Ltd**

Attention: **Roger Morton**

Reported by: **Anna Arkhireeva**
Polymer Centre
London Metropolitan University

Date of report: **21 August 2006**

1. Introduction

At the request of Dr Roger Morton of Axion Recycling Ltd, Melt Flow Rate, Heat Deflection Temperature, Impact and Tensile Strength measurements were performed for 4 recycled HIPS samples.

2. Experimental

The test samples were injection moulded using a Klockner Ferromatic F60 injection moulding machine. For samples AX 06 007 and 008, the barrel temperature was between 215^{0}C (nozzle) and 200^{0}C (rear), for AX 06 006, between 195^{0}C and 185^{0}C, respectively, and for AX 06 009, between 225^{0}C and 210^{0}C. The mould temperature of 30^{0}C was used for AX 06 006 sample and for samples AX 06 007, 008 and 009 the mould temperature was 40^{0}C. The materials were dried prior to moulding for approximately 1.5 hours at 70^{0}C

All the tests were performed at 22-23^{0}C, at *ca.* 40% humidity.

Izod impact tests were performed using a Ray-Ran Pendulum Impact system with the hammer weight of 0.898 kg at velocity of 3.5 m/s. The standard specimen measures 80 x 10 x 4 mm. For the notched geometry of the specimens, the depth under the notch is 8 mm. At least 8 specimens were used for each individual test. The tests were performed according to ISO 180:1993(E) standard.

Melt Flow Rate measurements were carried out using a standard Davenport melt flow indexer equipped with a Eurotherm temperature controller in accordance with BS EN ISO 1133:2000 BS2782-7:Method 720A at 200^{0}C using the weight of 5.0 kg.

Tensile measurements were carried out on a Tinius Olsen H10KS tensometer at 50 mm/min using the grip distance of 115 mm and the gauge length of 50 mm. 6-8 dumb-bell specimens were used for each compound. ISO 527 (BS 2782-3) standard was used.

HDT tests were performed on a Ray-Ran HDT-Vicat softening point apparatus using flatwise specimen orientation (80 x 10 x 4 mm) with the temperature ramp rate of 120^{0}C/hour. The fibre stress of 1.8 MPa was used. The tests were carried out according to ISO 75-2:1993 standard.

3. Results

Some signs of plate-out are seen in mouldings produced with AX 06 007 (Fig. 1) and 008 compounds, thus suggesting that these materials are contaminated with some additives/polymers that are incompatible with HIPS. The best processibility and quality of the mouldings were observed for AX 06 009 sample (Fig. 2).
Both tensile and impact test pieces fractured in the way similar to that expected for virgin HIPS samples. The results of the Izod impact tests show a considerable separation between the values obtained for the notched and unnotched geometry. This observation suggests that the materials studied here are quite sensitive to defects and flaws. Typical tensile load-displacement curves were obtained for all the compounds. These curves show that tensile fracture of these samples involves necking and cold-drawing. Stress whitening was clearly seen during the test. However, this stress-whitened zone ‘healed’ after the fracture was completed. The only notable feature is that for AX 06 009 sample the gap between the yield

stress and the necking/cold-drawing stress value is very small (almost negligible) as compared to the curves obtained for AX 006, 007 and 008 samples.

For all the compounds, tensile strength values are in the middle of the range typical of virgin unfilled HIPS. Only for AX 06 009 compound, the impact strength value is significantly lower than that characteristic of virgin HIPS grades. On the other hand, only for this material the HDT value is within the range observed for virgin HIPS, whereas lower HDT values were measured for the remaining three compounds.

The results are summarised in Table 1.

Table 1. Properties of recycled HIPS samples

Material	AX 06 006 Centrevap process large scale trial Run 3 product	AX 06 007 Centrevap process large scale trial Run 4 product	AX 06 008 Centrevap process large scale trial Run 4 product after further pass through twin screw extruder	AX 06 009 Creasolv process large scale trial 4th pass through ring extruder	Typical unfilled virgin	
					HIPS	ABS
Izod impact unnotched (kJ/m^2)	43.6∀13.3	48.9∀8.0	60.6∀18.0	26.2∀6.5	-	-
Izod impact notched (kJ/m^2)	10.6∀0.7	10.8∀0.2	10.7∀0.4	4.9∀0.9	10-20	15-45
Tensile Modulus (MPa)	1800∀650	2000∀360	1750∀390	2080∀310	1500-2500	2000-2300
Tensile strength (MPa)	16.4∀0.8	24.4∀0.2	24.7∀0.3	33.0∀0.2	13-42	35-50
Elongation at break, %	31.2∀17.3	32.7∀4.3	35.7∀5.2	29.9∀4.1	20-65	20-25
MFI (g/10min)	46.7∀1.8	16.0∀1.2	16.4∀0.9	2.73∀0.03	-	-
HDT, ^{0}C	51	69	69	82	75-95	90-100

Figure 1. Tensile dumb-bells injection moulded using AX 06 007 material (Centrevap trial run 4)

Figure 2. Tensile dumb-bell specimen injection moulded using AX 06 009 material (Creasolv trial after 4th pass through ring extruder)

Further report on testing of final product from large scale Creasolv process trials in Phase 3

Melt Flow Rate, Heat Deflection Temperature, Tensile and Impact Strength Analysis

Recycled HIPS Sample

Report No. 2046

Client: **Axion Recycling Ltd**

Attention: **Roger Morton**

Reported by: **Anna Arkhireeva**
Polymer Centre
London Metropolitan University

Date of report: **4 October 2006**

1. Introduction

At the request of Dr Roger Morton of Axion Recycling Ltd, Melt Flow Rate, Heat Deflection Temperature, Impact and Tensile Strength measurements were performed for a recycled HIPS sample.

2. Experimental

The test samples were injection moulded using a Klockner Ferromatic F60 injection moulding machine. The barrel temperature was between 215^{0}C (nozzle) and 200^{0}C (rear) and the mould temperature of 40^{0}C was used. The material was dried prior to moulding for approximately 1.5 hours at 70^{0}C

All the tests were performed at 20-22^{0}C, at *ca.* 40% humidity.

Izod impact tests were performed using a Ray-Ran Pendulum Impact system with the hammer weight of 0.898 kg at velocity of 3.5 m/s. The standard specimen measures 80 x 10 x 4 mm. For the notched geometry of the specimens, the depth under the notch is 8 mm. 12 specimens were used for each individual test. The tests were performed according to ISO 180:1993(E) standard.

Melt Flow Rate measurements were carried out using a standard Davenport melt flow indexer equipped with a Eurotherm temperature controller in accordance with BS EN ISO 1133:2000 BS2782-7:Method 720A at 200^{0}C using the weight of 5.0 kg.

Tensile measurements were carried out on a Tinius Olsen H10KS tensometer at 50 mm/min using the grip distance of 115 mm and the gauge length of 50 mm. 10 dumb-bell specimens were used. ISO 527 (BS 2782-3) standard was used.

HDT tests were performed on a Ray-Ran HDT-Vicat softening point apparatus using flatwise specimen orientation (80 x 10 x 4 mm) with the temperature ramp rate of 120^{0}C/hour. The fibre stress of 1.8 MPa was used. The tests were carried out according to ISO 75-2:1993 standard.

3. Results

The results are summarised in Table 1.

Table 1. Properties of recycled HIPS sample

Material	AX 06 50 Creasolv process large scale trial 3rd pass through ring extruder
Izod impact unnotched (kJ/m^2)	26.37∀4.22
Izod impact notched (kJ/m^2)	5.73∀0.49
Tensile Modulus (MPa)	2280∀160
Tensile strength (MPa)	30.7∀0.1
Elongation at break, %	15.6∀4.2
MFI (g/10min)	3.86∀0.01
HDT, ^{0}C	80∀1

Appendix 3 – Evaluation of Ionic Liquid, Antisolv and RGS90 process designs

Ionic Liquid extraction

Process Developer: Brunel University, London

Status: Laboratory scale

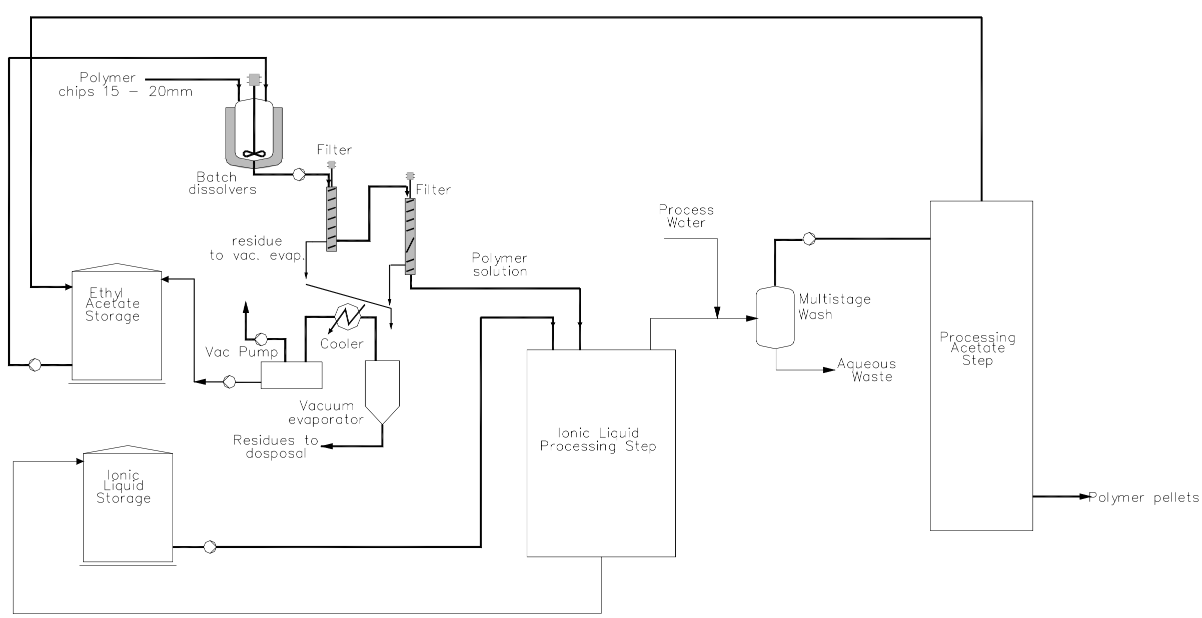
This process concept was proposed initially to WRAP by the Centre for Environmental Research at Brunel University. It was refined further as a result of discussions with Axion and other project partners and in the light of initial laboratory trials.

Brunel synthesised 13 different ionic liquids with the aim of producing a compound which would selectively dissolve the target brominated flame retardants without dissolving the polymer. One of these (1-hexylpyridinium bromide) was found to be particularly effective as a selective solvent for Deca BDE. WRAP has filed a patent application to cover the synthesis method and the use of this and related compounds for extraction of brominated flame retardants. The chosen ionic liquid is involatile and is a solid at room temperature. It melts to form a semi-viscous liquid above about 50C.

The original process concept was to extract BFRs from solid polymer particles however initial laboratory tests indicated that this would not be commercially viable due to the low diffusion rate of the ionic liquid into and out of solid polymer particles.

The concept was then modified to use the ionic liquid as an agent to extract brominated flame retardants from a solution of the polymer in a second, immiscible solvent. After several trials at Brunel Ethyl Acetate was chosen as the most appropriate solvent for the polymer and a process design was developed based on this work.

Flowsheet



Process description

Ethyl acetate is used to dissolve the polymer. A bulk supply of this solvent is stored under ambient conditions in a stainless steel storage tank. The tank also receives ethyl acetate recovered from the process. It is assumed that the solvent will be delivered in bulk tankers and sufficient ullage will be provided to off load 22000 litres of solvent whilst still maintaining production.

Ground, segregated plastic waste is dissolved in ethyl acetate in one of two batch agitated dissolving vessels. Ethyl acetate is added to the dissolution vessel and then the plastic waste added. The polymer solubilisation is carried out at ambient temperature.

The solvent dissolves all the polymer and bromine containing compounds in the dissolution vessel. An excess of solvent is used at this stage to minimise the viscosity of the solution allowing filtration to take place.

Undissolved material is filtered out. Experimental work has shown that a two stage filtration system is necessary, the first stage using 1mm mesh and the second stage using 50 micrometre mesh. A single pump draws from each dissolver in turn to give a continuous feed to the filters. The filters are self cleaning and will discharge the collected solids intermittently into a drum for disposal off site, probably by incineration. The filter residue is expected to contain about 50% solvent by weight.

An Ionic Liquid (hexyl pyridinium bromide) is stored in a bulk stainless steel tank, held by steam heating at about 70oC, as the chosen material is solid at room temperature. The ionic liquid and polymer solution are mixed in a stirred tank and then passed to a settling vessel to separate out two layers. A coalescing filter within the settler aids separation. The mixer and separator are maintained at about 80 to 85oC by operating under a positive pressure.

The upper polymer layer in ethyl acetate is sent for recovery of the polymer. The ionic liquid layer is treated to recover the extracted BFRs.

The remaining part of the process description is currently confidential to WRAP, pending filing of a patent application.

EFFLUENTS PRODUCED

Water Effluent

A major effluent source is the water used to wash the ionic liquid from the polymer solution. The estimated quantity of wash water needed is about 14.5 tonnes per hour.

The stream will contain some plastics dissolved up in the solvents. The stream is hot during the washing stage and will need to be cooled before discharge to sewer. Some of the dissolved solids may well precipitate. The dissolved polymer will therefore be treated as suspended solids.

The COD value is calculated as 38000 mg O2/litre.

The cost of treatment of this effluent by a UK water authority would be approximately £165 per hour

Vapour Effluent

Vacuum stripping of ethyl acetate of the precipitated polymer will produce a vapour effluent high in VOC. Knock back condensers will be used to control this, but this emission may need to be further reduced using activated carbon once detailed design is carried out to quantify the amount being emitted.

The underwater pelletiser itself will produce little VOC emission, but the carried water will become saturated with ethyl acetate and may require the intermediate storage tank to be vented through active carbon.

Solids

Solid wastes are produced at the polymer filtration step (to remove inerts from the polymer) and the BFR disposal step. In both cases the solids will be discharge in solvent suspension. The solid wastes produced will be discharged from site for incineration. The assumption is that there is 2% insoluble (inert) material in the feed and the discharge can be achieved as an 80% dry cake.

Business model

The Ionic liquid extraction process is projected to be loss-making:

Ionic liquid process business model

£'000	Year 1	Year 2	Year 3	Year 4	Year 5
Profit and Loss					
Sales Value	0	1,658	3,552	4,736	4,736
Operating costs	-770	-4,154	-4,154	-4,154	-4,154
EBITDA	**-770**	**-2,497**	**-602**	**582**	**582**
Interest	-106	-206	-169	-93	-44
Depreciation	-135	-541	-541	-541	-541
Pre-tax profit	-1,012	-3,244	-2,788	-52	-3
Taxation (estimate)	0	0	0	0	0
Net profit	**-1,012**	**-3,244**	**-1,312**	**-52**	**-3**
Operating Cash Flow					
Revenues (inc VAT)	0	1,948	4,174	5,565	5,565
Construction costs (inc VAT)	-3,178	-3,178	0	0	0
Operating costs (inc VAT)	-905	-4,881	-4,881	-4,881	-4,881
Debt Service	-232	-920	-955	-906	-492
VAT (paid)/recovered	567	873	188	-81	-102
Corporation tax (approx)	0	0	0	0	0
Dividends paid	0	0	0	0	0
Surplus	**-3,748**	**-6,159**	**-1,474**	**-303**	**90**
Balance sheet					
Fixed assets	2,570	4,734	4,193	3,652	3,111
Current assets	-968	-4,422	-5,896	-6,199	-6,109
Current liabilities	1,456	2,328	1,625	832	384
Net assets	145	-2,016	-3,328	-3,380	-3,383
Equity	1,157	2,239	2,239	2,239	2,239
P&L account	-1,012	-4,255	-5,567	-5,619	-5,622
	145	-2,016	-3,328	-3,380	-3,383

Capital cost of the plant is estimated at £5.4 million on an existing UK chemical site. The projections assume that a further £4.0 million of working capital will be required in the first two years.

Discussion

The ionic liquid developed by Brunel is a very efficient selective solvent for brominated flame retardants. The solvent has low volatility, which is a potential advantage. With further process development it could potentially produce an interesting process design.

The current embodiment of the process generates too much effluent, consumes too much secondary solvent (ethyl acetate) and uses too much energy for commercial or environmental viability.

The process design modelled is a scale up of the laboratory scale work done at Brunel. Despite considerable process design brainstorming by Axion and the rest of WRAP project team we were unable to identify design modifications which could simplify the process significantly or reduce its resource consumption.

A further fundamental issue with this process is that the ionic liquid used is itself brominated. The process removes BFRs effectively but inevitably small amounts of ionic liquid will be left in the polymer, reintroducing bromine to the polymer

Brunel tested other analogues of the chosen ionic liquid but none were as effective as the brominated version.

The business model indicates that the process is likely to generate substantial annual losses with the target gate fee of £45/te.

Antisolv

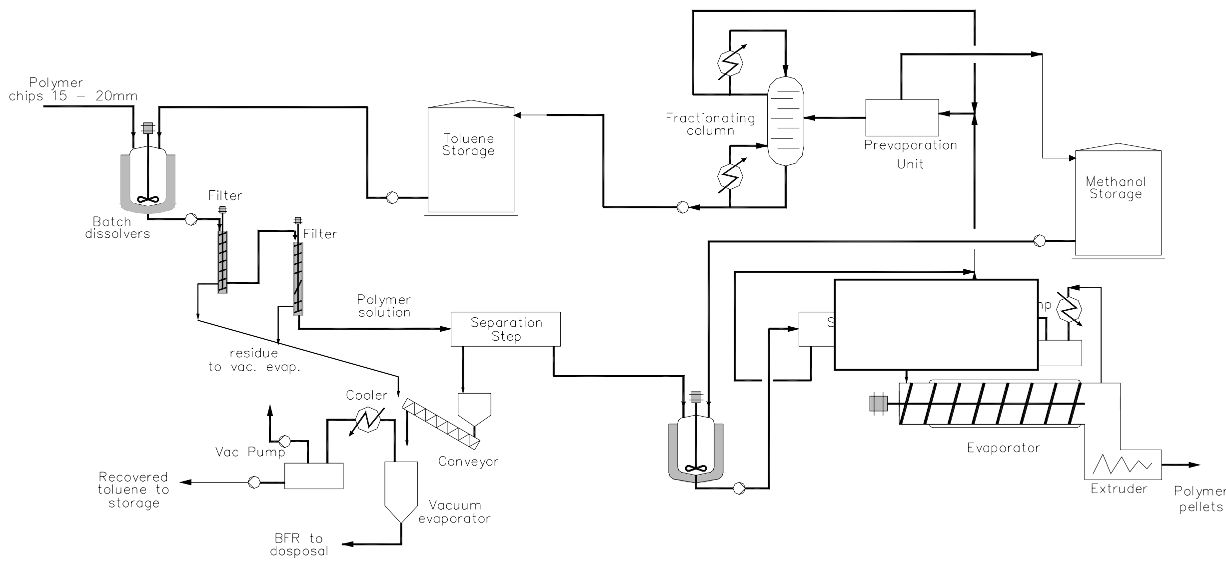
Process Developer Nottingham University

Status Laboratory trials conducted

This process is a variation on the Centrevap process described at section 0. The same technique is used to separate insoluble particles of BFR and other additives from a solution of the polymer in a solvent such as toluene.

Instead of simply evaporating the solvent from the polymer a second solvent is added to cause the polymer to precipitate from solution. This technique is known as anti solvent precipitation.

Flowsheet



Process description

Toluene is used to dissolve the polymer. A bulk supply of the selected solvent is stored under ambient conditions in a carbon steel storage tank.

The tank also receives recovered solvent from the process. It is assumed that the solvent will be delivered in bulk tankers and sufficient capacity will be provided to off load 22000 litres of solvent whilst still maintaining production.

Ground, segregated plastic waste is dissolved in solvent in one of two batch agitated dissolving vessels. Solvent is added to the dissolution vessel and then the plastic waste added. The polymer solubilisation can be carried out at ambient temperature, but works better at slightly elevated temperatures, e.g. 40oC to 60oC. An excess of solvent is used at this stage to minimise the viscosity of the solution allowing filtration to take place.

The slurry formed in the dissolvers will be pumped to a solids removal step (currently confidential pending possible filing of a patent application by WRAP). These will include all un-dissolved plastics, metals, wood, fillers from the dissolved polymer and the un-dissolved brominated flame retardants.

The solids are discharged to a collecting vessel and then conveyed to a solvent recovery system. This will recover the solvent and produce a dry residue which can be packed into drums for off site disposal to landfill or for recycling of the BFR component by the bromine industry

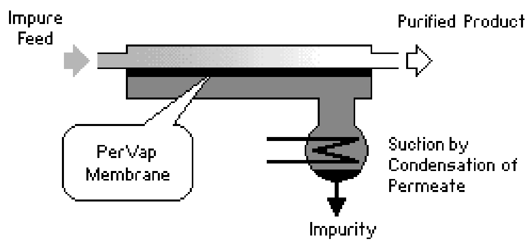
Methanol is then mixed with the polymer solution in a mixing tank. This causes the polymer to precipitate. The solids are removed from the liquid suspension in a separator (details currently confidential). Experiments conducted at Nottingham University suggest that the precipitated material is approximately 25% polymer and 75% solvent. The surplus solvent material must be evaporated and the solvent driven off to a low level before the polymer can be extruded. The separated polymer granules will be processed in a horizontal evaporator and then passed through a vented extruder to produce polymer pellets for on sale.

The vapour from the evaporator is condensed and returned for reprocessing before being sent to storage and reuse in the process.

The mixed solvent of toluene and methanol is pumped to a separation system. This separation step involves both distillation and pervaporation over a membrane. The toluene methanol mixture forms an azeotrope in conventional distillation systems that cannot be broken except by a membrane process.

The products from the separation step are 99 mole % toluene and about 95 mole % methanol.

General characteristics of pervaporation are:



- Uses semi-permeable membrane
- Permeate leaves membrane in vapour state
- Permeate must be volatile at operating condition
- Functions irrespective of vapour/liquid equilibrium
- The overhead vapours from the pervaporator are condensed and returned to the storage tank for reuse.

EFFLUENTS PRODUCED

Water Effluent

None

Vapour Effluent

The extruder producing the final polymer for sale will generate VOC vapour effluent as the polymer is heated during the passage through the extruder. This stream will pass to a condenser to capture any residual solvent for re-use followed by an active carbon filter if necessary to reduce the emission of VOC.

Solids

Solid wastes containing BFR and inerts are produced in a slurry with toluene at the centrifuge/filter step. As a "best guess" this has been taken as 50% by weight of solvent. The slurry is dried to recover residual toluene in a batch solvent recovery unit. The dried residue is packed into drums for off site disposal. This may either be to landfill or back to the bromine industry for bromine recovery.

Business model

The Antisolv process is projected to be marginally profitable:

Antisolv process business model

£'000	Year 1	Year 2	Year 3	Year 4	Year 5
Profit and Loss					
Sales Value	0	1,677	3,595	4,793	4,793
Operating costs	-770	-3,736	-3,736	-3,736	-3,736
EBITDA	**-770**	**-2,059**	**-142**	**1,056**	**1,056**
Interest	-178	-347	-287	-162	-80
Depreciation	-233	-932	-932	-932	-932
Pre-tax profit	-1,181	-3,338	-2,891	-38	44
Taxation (estimate)	0	0	0	0	-13
Net profit	**-1,181**	**-3,338**	**-1,361**	**-38**	**31**
Operating Cash Flow					
Revenues (inc VAT)	0	1,971	4,224	5,632	5,632
Construction costs (inc VAT)	-5,476	-5,476	0	0	0
Operating costs (inc VAT)	-905	-4,390	-4,390	-4,390	-4,390
Debt Service	-418	-1,547	-1,612	-1,538	-890
VAT (paid)/recovered	909	1,158	109	-164	-185
Corporation tax (approx)	0	0	0	0	0
Dividends paid	0	0	0	0	0
Surplus	**-5,889**	**-8,283**	**-1,670**	**-461**	**166**
Balance sheet					
Fixed assets	4,427	8,155	7,223	6,291	5,359
Current assets	3,771	147	-1,523	-1,983	-1,817
Current liabilities	2,515	4,093	2,852	1,497	719
Net assets	5,683	4,209	2,848	2,811	2,823
Equity	6,864	8,728	8,728	8,728	8,728
P&L account	-1,181	-4,519	-5,880	-5,917	-5,905
	5,683	4,209	2,848	2,811	2,823

Capital cost of the plant is estimated to be £9.6 million on an existing UK chemical site. The projections assume that a further £5.0 million of working capital will be required in the first two years.

Discussion

The concept behind this process idea was to reduce the energy consumption of the Centrevap process option by using anti-solvent precipitation to remove most of the solvent from the polymer.

Lab trials and subsequent process design worked identified two fundamental problems which limit the commercial viability of this option:

- All of the anti-solvent combinations tested form an azeotrope when they are separated for re-use. An azeotrope is a solvent mixture which cannot be separated by conventional distillation. This necessitates an expensive pervaporation step to recover the solvents for re-use
- A relatively large proportion of the second solvent (methanol) must be added to the polymer solution in order to obtain a reasonable reduction in solvent content. Even then the residual solvent left on the polymer is still significant.

Pervaporation processes are now commercial for some applications, such as splitting toluene and methanol or ethanol and water. However the flow rate required in this case is larger than the largest commercially built units by a factor of 2. There is a risk in scaling this process by this factor. Additionally it is not clear what the effect of residual polymer in the azeotrope might be on the membrane within the unit. The development of the anti solvent process will include a significant amount of development of the pervaporation process.

The business model indicates that the Antisolv process is likely to be marginally profitable at full output with the target gate fee of £45/te. However the high capital cost means that investor returns would be negative.

RGS90 Sigsnaes

Process Owner: RGS90 AS Waste management company, Denmark.

An option for disposing of WEEE plastics containing brominated flame retardants could be to feed them with PVC to the RGS90 Stigsnaes plant.

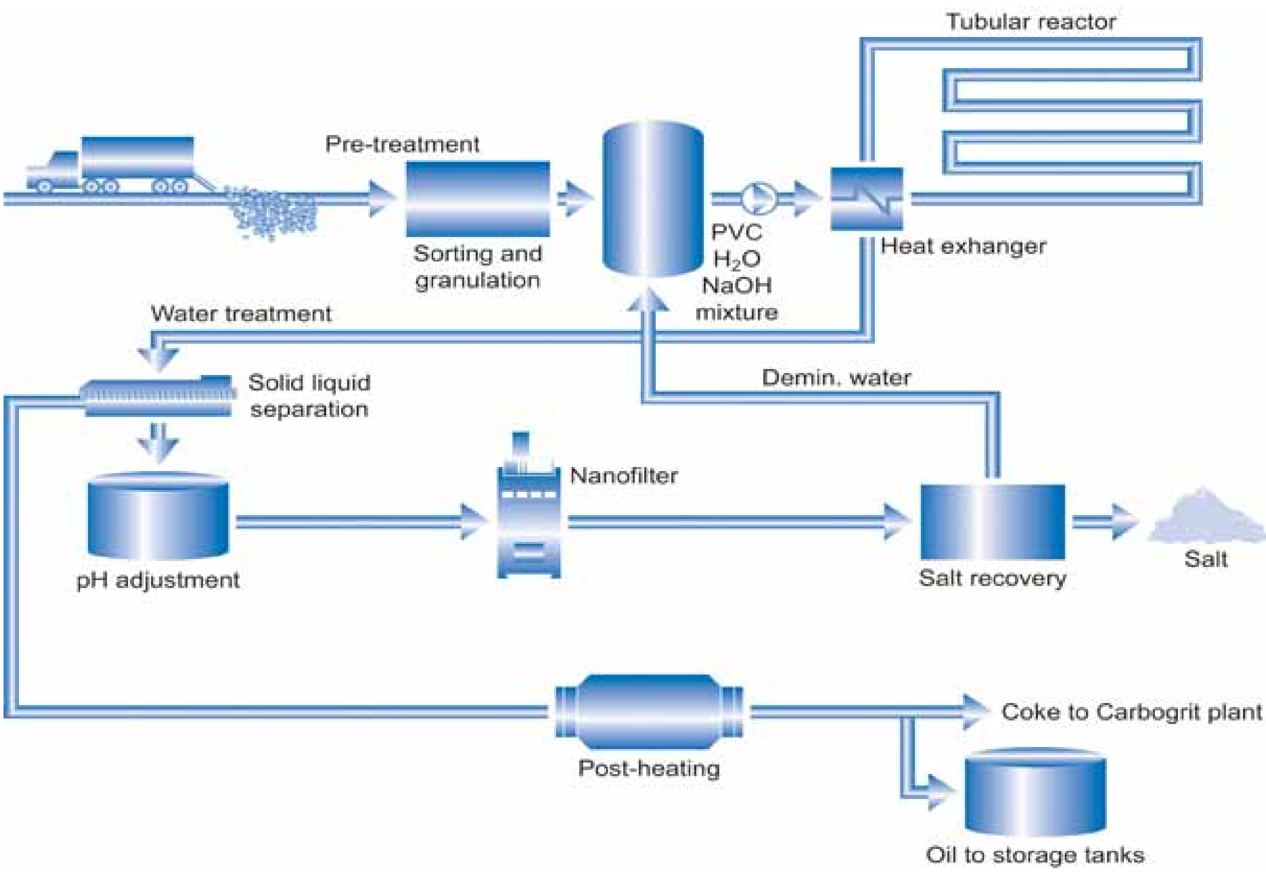
RGS90 is a waste management company based near Copenhagen which has developed a range of novel large scale treatment solutions for difficult waste streams originating in Denmark and northern Europe.

The RGS90 Stigsnaes plant is a feedstock recycling process that was been developed to treat waste PVC. Development of this process was part-funded by the European Union and by the PVC industry through its Vinyl2010 sustainability initiative[10].

The Stigsnaes plant has a large capacity (40,000te/yr) and could easily accommodate a stream of BFR polymer alongside PVC if it could be proved that the PVC hydrolysis process would also be effective for treating styrenic BFR-containing polymer.

Unfortunately the plant was moth-balled during 2005 because RGS90 found it difficult to achieve the high gate fees that were required to make the process profitable.

Flowsheet



RGS90 Stigsnaes flowsheet[11]

[10] www.vinyl2010.org
[11] Diagram courtesy of E Rasmussen, RGS90, Denmark

Process description

The Stigsnaes process is a new process, with the first commercial plant built recently in Denmark. The plant has been developed to treat PVC although we have been informed that the process can also treat BFR containing polymers.

Mixed plastic waste is shredded and fed to a heated mixing vessel where it is mixed with caustic soda solution to form a suspension. The mixture is then pumped through a heat exchanger into a pipe hydrolyser where the bromine and chlorine-containing plastics hydrolyse to sodium bromide, sodium chloride and denatured plastics. The operating plant is reported to have the equivalent of 6km of pipe in the hydrolyser with the hydrolyser operating at temperatures up to 260oC and pressures of 100bar.

After hydrolysis, the substance is divided into a liquid fraction and a dry fraction. The dry part consists of denatured plastic waste, from which the bromine content has been removed. This is filtered, discharged and sent for further treatment in a pyrolyser. The wet part consists mainly of sodium bromide salt, some of the phthalates and the heavy metals. These are separated by a nano filtration process to produce clean sodium bromide, which is evaporated and crystallized. The remaining unwanted materials from the nano filtration step are also fed to the pyrolysis process.

The RSG90 process works in conjunction with the nearby Carbogrit process that takes sewage sludge and coke to produce an expendable shot blasting media. Excess heat from the Carbogrit process is used to heat the Stigsnaes process to help accomplish the pyrolysis step.

The dry part now undergoes the process of pyrolysis, where it is heated and decomposes into oil and coke. All the phthalates in the BFR polymer end up in the pyrolysis furnace and are converted to oil. All the heavy metals end up in the coke fraction and are purified by the Carbogrit process.

The coke produced from the waste replaces new coke in the Carbogrit process and lime and minerals in the coke fraction become part of the Carbogrit end product. A fraction of the oil which is produced is used as fuel for the pyrolyser and the remaining oil is sent to a conventional crude oil refinery for further processing mixed with normal crude oil.

Effluents Produced

Water Effluent

De-mineralised water. This is bled from the de-mineralised water recycle stream.

Vapour effluent.

Combustion gases from the pyrolyser are passed to an air pollution control system which reduces emissions below Danish statutory limits.

Solids

Filter residue which consists of inerts and metals. The metals are recovered and sold, and the inerts are used in the Carbogrit process.

Business model

RGS90 does not disclose its detailed operating costs. However it has disclosed enough information to this project (under non-disclosure agreement) to allow Axion to make an evaluation of the likely variation in RGS90's gate fee in the event that processing of styrenic polymers is technically feasible using the RGS90 process.

Costs incurred for BFR polymer waste arising in the UK would include transportation costs in transporting the waste to Denmark and the plant gate fee.

Compared to the hydrolysis of PVC, BFR polymers require far less sodium hydroxide solution therefore the raw material cost should be less when processing BFR polymers. Currently the gate fee for PVC fed to the plant stands at £120/te.

As BFR polymer requires less sodium hydroxide than PVC and will also produce more crude oil from the polymer fraction the gate fee required for BFR feed so that the plant maintains its existing profit levels could be as low as £42/te.

Transport of waste polymer from UK to Denmark would add at least a further £50/te, leading to a total processing cost of just under £100/te. The business models for the other BFR treatment processes reviewed in this study assume a gate fee of £35/te.

There would be no additional capital costs associated with the process if polymer waste could be processed alongside PVC in the existing Stigsnaes plant in Denmark.

Recovery of the capital cost of the Stigsnaes plant is embodied in the gate fee currently charged by RGS90.

Because the Stigsnaes plant is a conversion of an existing plant originally built for another purpose and has also received substantial grant support a new plant built in the UK would be considerably more expensive

Discussion

The RGS90 process has not been proven as an option for debromination of BFR polymers in practical trials.

However discussions with RGS90 regarding their extensive experience of pyrolysis debromination of WEEE polymers and their experience of sodium hydroxide hydrolysis of PVC indicate that if a stream of WEEE polymer is processed alongside PVC in the Stigsnaes plant there is a good chance that the process will extract the bulk of the bromine and produce a crude oil with potential for use as a chemical feedstock.

The outline business modelling conducted in collaboration with RGS90 indicates that the cost of processing this material alongside PVC should be lower for BFR polymer than for PVC. However this calculation includes assumptions regarding the crude oil quality that have not yet been proven. Brominated flame retardants will be considerably more difficult to hydrolyse than PVC. There is a good chance that significant quantities of bromine will remain in the crude oil product. This could devalue the whole crude oil stream from the process and greatly reduce the financial viability of this process route.

The only way to prove the technical feasibility is to run a bulk trial with WEEE polymer in collaboration with RGS90. At present the Stigsnaes plant is moth-balled. For this reason no further work on this disposal option was proposed for Phase 3 of this project.

The projected cost of about £100/te to transport BFR polymer waste from the UK to Denmark and then process it in the Stigsnaes plant at a reduced gate fee compared to PVC is not competitive with the projected commercial performance of the Creasolv and Centrevap process options. Both of these are projected to generate a profit at a gate fee of £45/te.

Appendix 4 – Phase 2 development of Creasolv and Centrevap process designs

This section presents the initial process designs for the Creasolv and Centrevap process options that were developed and evaluated during Phase 2. It includes details of the early process trials that were conducted.

Both process designs were further developed considerably during Phase 3 of the project. The final process designs and the final commercial and environmental evaluations of the optimised processes are presented in sections **Error! Reference source not found.** and **Error! Reference source not found.** of the main report.

Creasolv

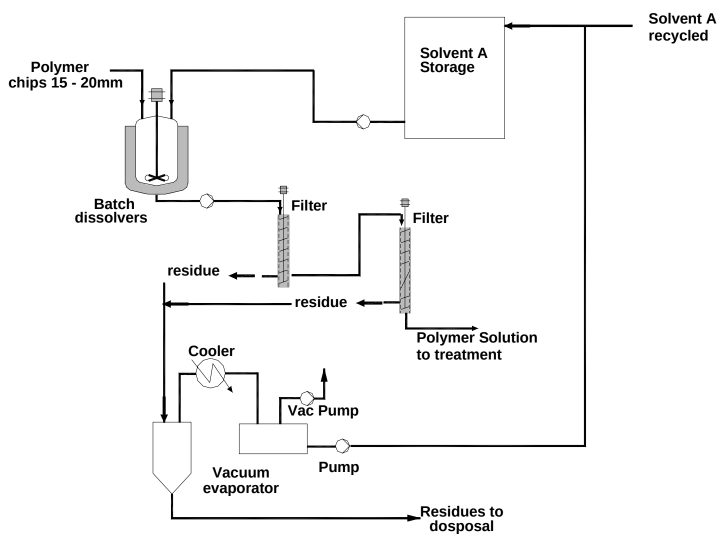
Process developer: Fraunhofer IVV Freising, Germany

Status at end of Phase 2: Technical scale development rig

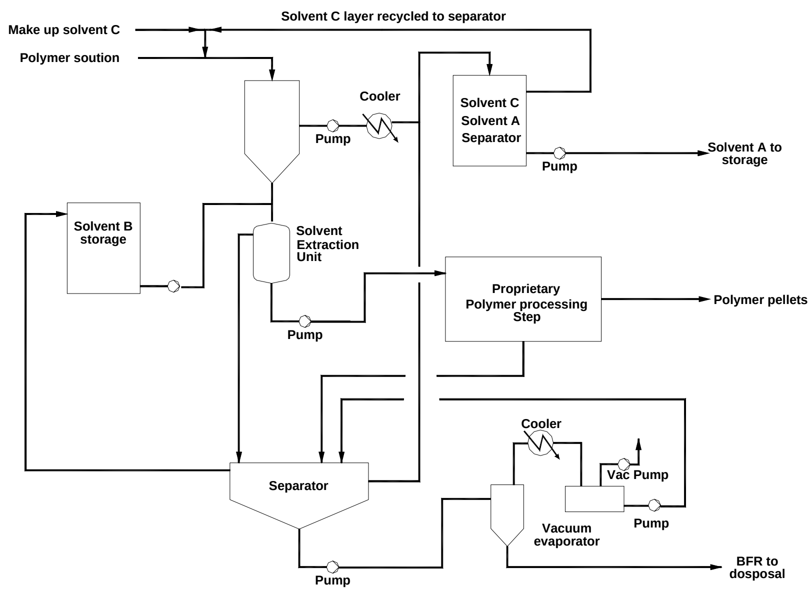
Dr Andreas Maeurer and his team at Fraunhofer IVV in Freising have spent several years developing this solvent separation process for WEEE polymers. The process concept is patented and there is a related company which plans to market the proprietary 'Creasolv' solvent mixture as a consumable.

A technical scale pilot facility is available at Freising for the dissolution, filtration, BFR-extraction and polymer-precipitation parts of the process while other aspects (solvent cycling, polymer drying and compounding at technical scale) have been tested at other facilities in Europe.

Creasolv process – Flowsheet – Phase 2



CreaSolv Process – Simplified Flowsheet for dissolution and primary filtration



CreaSolv Process – Simplified Flowsheet for Brominated Flame Retardant Removal

Process description

Plastic waste is ground to reduce its size and added to a dissolution vessel. CreaSolv solvent, a proprietary tailored solvent with a low vapour pressure, is added to the dissolution vessel.

The solvent dissolves all the polymer and bromine containing compounds in the dissolution vessel. An excess of solvent is used at this stage to minimise the viscosity of the solution allowing filtration to take place.

Undissolved material is filtered out. Solvent is recovered from the primary filter residue in a batch solvent recovery unit. The dried residue is packed in drums for disposal to non-hazardous landfill.

The solution of polymers is pumped to a vessel where some of the solvent is removed by anti-solvent precipitation.

The solution is then pumped into a solvent extraction unit. This causes the brominated materials to pass into a second proprietary Creasolv solvent, exploiting their differential solubility in the two different Creasolv solvents.

The bulk of the excess solvent is removed from the debrominated polymer in a special extraction unit before the polymer is passed to a vented compounding extruder to remove any residual solvent. This extruder may also be used to compound in performance additives and colour before discharging the product polymer for re-use.

Precipitated brominated flame retardants in the second solvent are separated by filtration. The filter residue is dried to recover any residual solvent for re-use, producing a dry residue which can be drummed off for disposal to landfill or for possible recycling by the bromine industry.

The recovered solvent vapours pass to a condenser system and are separated for return to the dissolver step.

EFFLUENTS PRODUCED

Water Effluent

None

Vapour Effluent

The extruder producing the final polymer for on sale will generate solvent VOC effluent as the polymer is heated during the passage through the extruder. The bulk of this solvent will be recovered easily by condensation because both of the Creasolv solvents have high boiling points

Solids

BFR is discharged from the process in slurry in Creasolv solvent. The solvent is recovered and recycled from the slurry by the solvent recovery unit. There may be a very small amount of VOC emission when dropping the dried BFR into drums for disposal or recycling by the bromine industry.

Solid wastes are also produced from the primary filter residue at the solvent recovery unit. The solids will be discharged as a dry cake and transported from site for landfill disposal.

Practical trials

A 30Kg sample of real WEEE BFR polymer was collected in the UK for the practical process trial. The sample was obtained by hand-sorting scrap TV casings collected from civic amenity sites in Sheffield. The standard polymer markings on each casing were checked to identify polymer type and whether or not they contained flame retardant. Only those marked HIPS-FR were selected.

The sample was shredded and de-metalled at Mastermagnets Ltd in the UK then shipped to Fraunhofer IVV where two 10Kg runs of the modified Creasolv process were conducted (after first conducting a 5Kg run on the HIPS 'golden sample' material to check process conditions).

Fraunhofer IVV analysed the composition of the feed and product materials from the first run on real WEEE polymers:

	Feed material	Run 1 product	Regulatory limit
Deca BDE	6.86%	0.2%	0.1% (Draft RoHS Directive – limit may be removed)
Octa BDE	2.05%	0.015% (150ppm)	0.1% ('Penta Directive' & RoHS Directive)
Penta BDE	<30ppm (0.003%)	<30ppm (0.003%)	0.1% ('Penta Directive' & RoHS Directive)
TBPE	1.66%	0.016%	No limit
Total Bromine	8.44%	0.34%	No limit
Dioxin TEQ *	5.2	0.8	No formal limit set
Dioxin 'Sum 4' ppb	12ppb	1ppb	1ppb (German dioxin ordinance)
Dioxin Sum 5 ppb	15ppb	5ppb	5ppb (German dioxin ordinance)

* Sum of Nato/CCMS-I-TEQs for eight 2,3,7,8 polybrominated dioxins and furans in terms of ng I-TEQ/g

Yield of polymer from the first WEEE polymer run was 78%.

Creasolv TV casing Trial 1 – precipitated debrominated polymer

Unfortunately the second run on TV casings did not go as well as the first run due to a problem with recovery of the primary Creasolv solvent from the first run.

The second run produced a poor quality product. However useful lessons were learned which have been built into the large scale process design.

The first trial also produced attractive crystals of brominated flame retardant:

Creasolv TV casing Trial 1 precipitated flame retardant crystals

The BFR crystals were sent to Dead Sea Bromine Group (DSBG), a leading bromine company for assessment. DSBG indicated that it may be able to re-use this material as a feedstock to produce new bromine and that it might not need to charge a gate fee to process it.

The debrominated polymer product from the first run was sent to London Metropolitan University for extrusion and injection mounding trials trials and physical property testing.

The material was processed without difficulty in both the extruder and injection moulding machines and good quality test pieces were produced for the physical property tests.

Creasolv product before extrusion **Extruded**

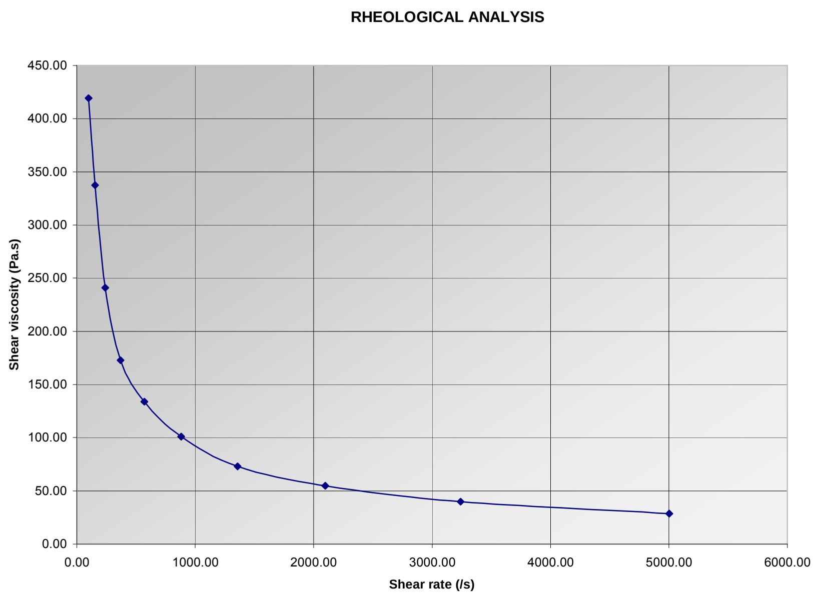
Test results were as follows:

Test	Creasolv Test 1	Typical virgin HIPS	Typical virgin medium impact PS	Typical virgin general purpose PS
Izod Impact notched (KJ/m2)	2.88	5.3-12	3.3-4.7	1.3-2.7
Heat Distortion Temperature ISO 75-2 (C)	75	99 max	99 max	104 max
Spiral flow plasticity ASTM D 123	19.2			

The heat distortion temperature for the Creasolv material was within the range expected for virgin HIPS.

However the Izod impact strength measured for the Creasolv sample was below the range normally expected for HIPS. It is at the top end of the range expected for general purpose polystyrene. This probably because there was still some residual solvent left in the product.

In addition a rheological curve was prepared for the material.



London Metropolitan University commented that this curve is within the normal range expected for virgin HIPS:

Centrevap

Process Developer Axion for WRAP

Status at end of Phase 2: Part of process tested at lab scale, evaporation step used at industrial scale for new polymers

The Centrevap process design was developed in the course of this project as a result of discussions between Axion and other project participants and observation of the results of other process trials conducted for the project. Similar process ideas have been patented previously in the US but differ in detail to the concept proposed here[12].

Basis for the process design

It was observed there is a difference in solubility between WEEE polymers and the additives they contain and that this could be exploited to remove the insoluble additives.

Several different solvents can be used to dissolve the styrenic polymers found in WEEE. Some of these solvents do not dissolve some of the brominated flame retardants, particularly decabromodiphenyl ether.

Data obtained from product data sheets and research carried out for this project by Nottingham University indicates the following approximate solubilities for BFRs of interest to this project:

Solubilities g/100g solvent at 20C

Solvent	Penta BDE	Octa BDE	Deca BDE	TBBA	TBPE	Antimony trioxide
Methyl Ethyl Ketone	C	16	<0.1	168	<0.1	<0.1
Toluene	C	7	0.2	6	0.3	<0.1
Tetrahydrofuran	C	70-80		C	0.5-1	<0.1
Dichloromethane	C	12	0.1	27	1.3	<0.1
Methanol	C	0.3	<0.1	80	<0.1	<0.1

C= Complete solubility

The table above indicates that Deca BDE, TBPE and antimony trioxide have low solubility in methyl ethyl ketone, toluene, tetrahydrofuran and dichloromethane at close to ambient temperature

TBBA also has relatively low solubility in toluene at ambient temperature but is fully or partly soluble in MEK, THF and dichloromethane.

Nottingham University also conducted qualitative tests of the solubility of ABS, HIPS and ABS/PC in a range of solvents for this project:

Solvent	HIPS	ABS	ABS/PC
Methyl Ethyl Ketone	Dissolved rapidly to slightly milky solution	Dissolved rapidly to milky solution	Polymer looked degraded, expanded and cracked. Some colour from polymer seen in solution
Toluene	Dissolved rapidly	Completely insoluble. Polymer swelled slightly and slight colour change	Polymer insoluble. Looked degraded, expanded and cracked. Some colour from polymer seen in solution
Tetrahydrofuran	Dissolved rapidly	Dissolved rapidly	Dissolved rapidly
Dichloromethane	Dissolved rapidly	Dissolved rapidly	Dissolved rapidly
Dimethyl formamide	Dissolved rapidly to slightly milky solution	Dissolved rapidly to slightly milky solution	Dissolved rapidly to milky solution
Chloroform	Dissolved rapidly	Dissolved rapidly	Dissolved rapidly

[12] US Patent 5,824,709, Oct 1998, 'Method for recycling waste plastic material containing styrene polymer' Motoshi Suka

Solvent	HIPS	ABS	ABS/PC
Diethyl ether	Insoluble but polymer appeared to become jelly-like with loss of shape	Completely insoluble. Polymer swelled and turned pale in colour	Completely insoluble. Polymer swelled and turned pale in colour
Methanol	Completely insoluble, no changes observed	Completely insoluble. Swelled slightly and turned pale	Completely insoluble, no changes observed
Hexane	Completely insoluble. Polymer swelled slightly and slight colour change	Completely insoluble. Slight colour change	Completely insoluble, no changes observed
Acetonitrile	Completely insoluble. Polymer swelled slightly and colour turned slightly more vivid	Polymer dissolved forming a milky solution	Polymer looked degraded, expanded and cracked. Some colour from polymer seen in solution

Three different behaviours were observed according to the solubility ability of the solvent. These are:

- Anti-solvent (methanol, hexane)
- Plasticizer (diethyl ether)
- Solvent (chlorinated solvents, methyl ethyl ketone, THF, DMF, toluene)

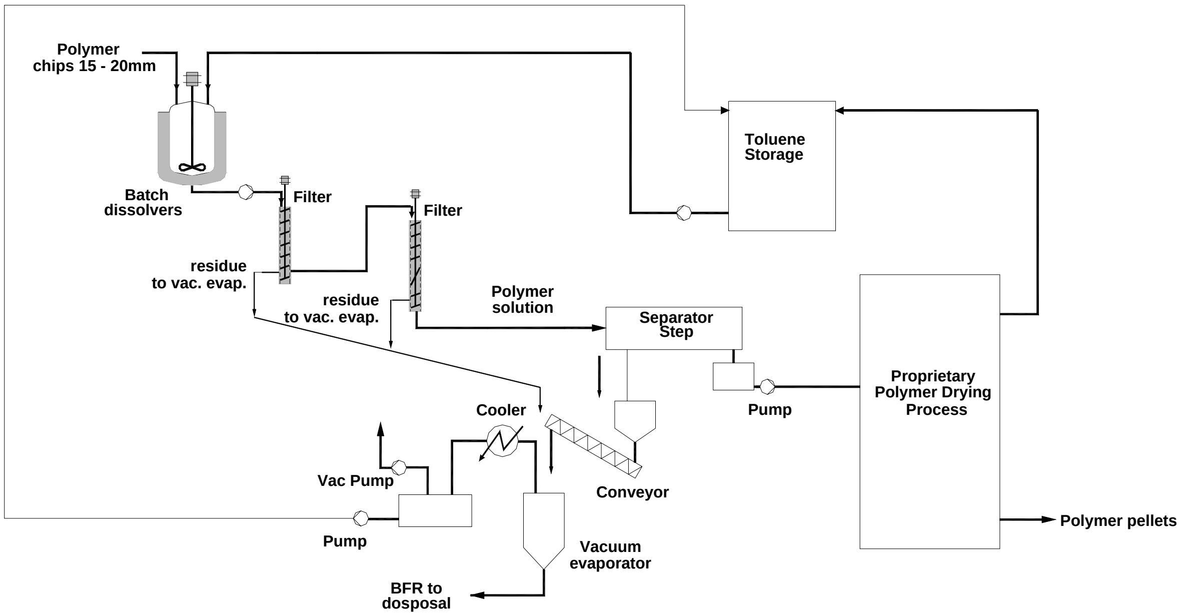
In the cases where the polymer dissolved a more or less turbid solution was always formed. That could probably be explained by the presence of a small fraction of very long polymer chains remaining out of solution.

Unfortunately Penta BDE is completely soluble in all of these solvents and Octa BDE is partly soluble. This means that it will not be possible to use this process option to extract penta and octa BDE using conventional solvents.

However tests conducted for this project indicate that the amounts of these materials, particularly penta BDE, present in real WEEE polymers is rather small. Further trials must be conducted to establish the likely average concentration of Penta and Octa BDE in typical WEEE polymers of the type to be treated by this process.

If the concentration of Octa and Penta BDE is not too high then the process should still have commercial potential as a method for separating not just Deca BDE but also antimony trioxide and any other fillers and additives which are not soluble in the chosen solvent.

Flowsheet



Process description

In the version of the process modelled for this project toluene is used to dissolve the polymer. A bulk supply of the selected solvent is stored under ambient conditions in a carbon steel storage tank.

The tank also receives recovered solvent from the process. It is assumed that the solvent will be delivered in bulk tankers and sufficient ullage will be provided to off load 22000 litres of solvent whilst still maintaining production.

Ground, segregated plastic waste is dissolved in solvent in one of two batch agitated dissolving vessels. Solvent is added to the dissolution vessel and then the plastic waste added.

The remaining part of the process description is currently confidential to WRAP, pending possible filing of a patent application.

EFFLUENTS PRODUCED

Water Effluent

None

Vapour Effluent

The evaporator will be fitted with a condenser, but some solvent (VOC) will slip to atmosphere. A final clean up of this stream using activated carbon may be necessary to meet emission limits when detailed design is carried out. It will be more difficult to capture the Centrevap solvent than the Creasolv solvent because the Centrevap process uses lower boiling solvents

The extruder producing the final polymer for on sale will also generate further VOC effluent as the polymer is heated during the passage through the extruder. This effluent will be treated in the same manner as the vacuum pump exhausts.

BFR is discharged from the process in slurry in toluene. The toluene is recovered and recycled from the slurry by the solvent recovery unit. There may be a very small amount of VOC emission when dropping the dried BFR and fillers into drums for disposal.

Solids

Solid wastes are produced at the solvent recovery unit step. The solids will be discharged as a dry solid and discharged from site for disposal to landfill or re-use as feedstock by the bromine industry.

Appendix 5 – Environmental Impact Assessment detail

Appendix 5 is split into six sections:

A. White Young Green ISO14040 Qualitative and Quantitative Environmental Impact Assessment Report
B. Explanation of QWERTY analysis
C. QWERTY Analysis method used for this project
D. Detailed results of QWERTY analysis
E. White Young Green update report for Phase 3
F. Huisman update of QWERTY analysis for Phase 3