Glass Recycling Handbook

Assessment of Available Technologies

Remade Scotland

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Report prepared by

Remade Scotland

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We acknowledge that the list of companies mentioned in this report is not definitive and we are aware that other glass technologies may exist. However, through time we aim to develop as comprehensive a list as possible and welcome your input. Therefore, if you are aware of a company that you feel should be included, or have any comments please contact us.

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Foreword

“The Glass Recycling Technology Handbook is a comprehensive and detailed guide to glass handling, processing, specifications, performance and market criteria. Anyone already in the industry, or those thinking of making an investment in the technology, will find this an invaluable support in their decision making process. The Remade Scotland partnership is delighted to see this handbook available to people in Scotland, the industry and further a field. We would like to also thank all those involved in producing the guide. We hope that you will all take the opportunity to use the guide and benefit from the extensive list of contacts, expert information, data and products detailed within it”

Duncan Simpson – Chairman of Remade Scotland

"This Handbook neatly complements WRAP's 'Recycled Glass Market Study and Standards Review' which was updated in May 2003 and is due for its second update in April 2004. The market for recycled glass is both increasing and diversifying at an unprecedented rate, driven both by Government policy and market demand. Both established and new glass processors will find this Handbook an invaluable tool in exploiting the new opportunities which are presented. WRAP have been delighted to work with Remade Scotland in the preparation of this Handbook and look forward to helping ensuring that its impact is as high as it deserves to be."

Andy Dawe – WRAP Materials Sector Manager (Glass)

1. Introduction

Glass is an ideal material for recycling and in some cases can be used repeatedly without any deterioration in its physical properties. In recent years new legislative and fiscal drivers have contributed to increasing the desirability of recycling glass.

This has been the case with the glass manufacturing industry, encouraging them to use more recycled glass cullet in place of virgin raw materials. However as with all markets, pressure from legislation can only be effective if the processors can ensure that using recycled materials meet their customers' quality requirements. Furthermore, the type of glass available for recycling is not always the type most demanded by the end market.

To meet demands for higher quality cullet, new technology has been developed and introduced to the glass making industry that enables processors to improve cullet quality and make production more efficient.

The development of new and alternative markets for recycled glass has further contributed to the development of new technologies. Processing technologies have needed to keep pace with the variety of specifications introduced by these new end markets. These markets include: construction aggregates, filtration, blast cleaning, tiles & ornaments, decorative aggregates, fluxing agents and glass fibre applications.

There are many new technologies and services entering the UK marketplace designed to recycle glass. New technologies are manufactured in other countries and some vendors prefer partnerships rather than simply selling their equipment are all being introduced to the UK. The purpose of this document is to introduce those wishing to invest in glass processing technologies to the variety of equipment types and services which are available on the market today to aid the decision making process.

1.1. Glass types in the waste stream

There are several types of glass entering the waste stream each with different chemical compositions and physical properties. The most common type of glass is 'soda-lime', which consists of silica (SiO_2), soda ash (Na_2CO_3) and limestone ($CaCO_3$) with other small additives and is used for containers (bottles and jars), flat glass (glazed windows), domestic tableware and lighting (fluorescent tubes). Other types of glass that enter the waste stream include cathode ray tubes (CRT) from TV screens and PC monitors, lead crystal from tableware, heat resistant glass ('Pyrex') and glass fibre.

Currently flat and container glass make up the bulk of recycled glass but materials and technologies are constantly developing and the design of new processes should increase the range of glass types that can be recycled. Unfortunately if glass types for which there is no recycling potential end up in the waste stream, they are considered contaminants and must be removed when co-mingled with other recyclables.

The chemistry of different glasses can vary dramatically, significantly affecting their suitability for some end markets.

Container glass, which forms the bulk of recycled glass is collected through bottle banks, local authority kerbside collection schemes and collections from licensed premises whereas the majority of flat glass waste is off-cut or reject material from factories that process flat glass e.g. window and windscreen manufacturers, old windows from demolition & building work and glass from scrapped vehicles of which there is very little recovered at present.

When recycling glass back into these markets care must be taken to use only glass which has a similar composition to the primary feedstock, this will help prevent inclusions and other anomalies arising from feedstocks with varying melting points etc.

1.2. Market Limitations

There are many reasons, to recycle glass.

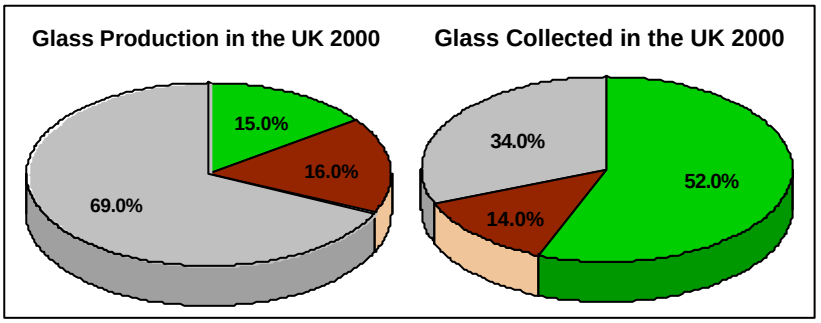
- About 8% to 10% by weight of domestic waste is glass and so recycling will reduce the costs of waste disposal, which currently stands at approximately £18 per tonne gate fee plus £14 per tonne landfill tax in the UK.
- Recycling is more sustainable as it requires less energy and fewer raw materials in new glass manufacturing than using virgin materials. One estimate is that a tonne of glass cullet saves energy equivalent to 135 litres of oil and 1.2 tonnes of primary raw materials[1]. Another estimate [2] gives a highly detailed analysis of the energy consumption, concluding that energy saving varies approximately linearly from zero to 17% as the proportion of recycled glass varies from zero to 100%.
- The need to comply with government regulations such as the European Community Directive on Packaging and Packaging Waste, the Climate Change Levy and the Integrated Pollution Prevention and Control Directive (IPPC) is currently driving the glass processors to use more recycled glass in place of virgin raw materials. The introduction of the Waste Electrical and Electronic Equipment (WEEE) Directive and the End-of-Life Vehicles (ELV) Directive in coming years will also encourage the recovery of glass from the waste stream.
- Longer furnace life - since by increasing the proportion of cullet to raw materials, the furnace can operate at slightly lower temperatures thus prolonging its life and reducing maintenance and replacement costs.

Despite all these advantages and pressures, the quality of processed recycled glass has been a major barrier to market development. As a result considerable effort has gone into research and development to address qualitative issues in recent years and to realise the many advantages of using recycled glass.

The major quality issues to be addressed are

- Contamination
- Colour sorting
- Moisture
- Dust control
- Particle size
- Particle shape

Also, there is an imbalance between the colours of container glass imported into the UK and the glass manufactured, which can potentially lead to surplus volumes of green glass being generated for which for which there is variable demand.



Clear glass containers account for 67% (1.15Mtonnes/year) of output from the UK glass container-manufacturing sector. This is largely caused by customers preferring to market their products such as whisky, alcopops and soft drinks in clear glass packaging. However, green glass imported through wine and beer bottles account for 52% (372kt tonnes) of recycled glass collected in the UK.

As recycling rates in the UK increase and the glass manufacturing industry reaches its capacity for utilising recycled green glass there will be a surplus of material. These circumstances have induced the need to develop alternative markets for recycled glass, which can utilise all types and colours of glass.

[1] http://www.nrf.org.uk/buy-recycled/buyrecycled/materials/glass.htm

[2] M Pavlovic, "Energy Savings in Crushed Glass in the Manufacture", in T H Christensen, R Cossu and R Stegmann (Eds.), Proceedings of the Seventh International Waste Management and Landfill Symposium, S. Margherita di Pula, Cagliari, Italy, 4-8 October, 1999

The factors driving the development of new technologies in the glass recycling industry can therefore be summarised as

- Increased support to increase recovery of glass to meet legislative requirements.
- The requirement to develop new markets so that the issue of colour imbalance in recycled cullet can be addressed.
- To meet the demands for greater quality standards.
- The need to develop markets which can utilise all types of glass

This report discusses the pressures on the glass industry that are driving the increases in the use of recycled cullet in glass manufacturing and other new developing markets, and presents, in some detail, the technologies that are available to address the quality and processing issues.

2. Factors Driving Glass Recycling

2.1. Existing Markets

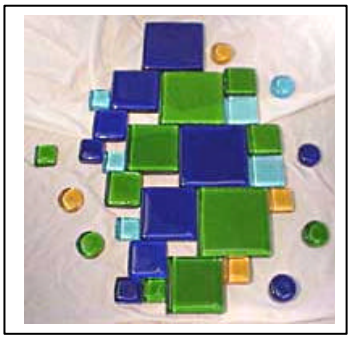
In recent years legislative pressures as well as improvements in cullet quality have greatly influenced the UK market for recycled glass. The Producer Responsibility Obligations (Packaging Waste) Regulations which came into force in March 1997 introduced the Packaging Recovery Note (PRN) system. This has made recycled glass more economically attractive and combined with the Climate Change Levy has made the lower energy requirements of using glass cullet as a raw material in place of virgin raw materials a key factor in reaching industry targets for reducing energy consumption. Similarly, the Pollution Prevention and Control (PPC) Regulations, which will be progressively implemented over an extended period to 2007, will set out targets to reduce pollution which glass companies will be required to meet and again increasing the amount of recycled cullet will assist the industry in meeting these targets.

In the long-term, these pressures can only influence the market for recycled glass if the products are of sufficient quality to meet customer demands. One of the major problems with recycling glass is contamination by a variety of unwanted materials and in some cases other colours of glass. Contaminants can damage new glass products, alter their physical properties and reduce their saleability and therefore end markets must demand high quality, contaminant-free cullet from the glass processors. Designing collection strategies and increasing public awareness to reduce contamination at the point of collection are effective and low cost measures that can be implemented to reduce contamination and Envirowise have produced a handbook that discusses this issue in some detail[1]. Typical contaminant levels in glass recovered from bottle banks is 150 - 300g/ tonne while the quality level required for container production is in the order of 20 -50 g/tonne. Once a contaminant has entered a batch of glass the only solution is removal but efficient removal of contaminants is costly for the processors and reduces any financial benefits they may derive from the use of recycled glass, thus making them reluctant to purchase poor quality cullet from collectors. Clearly, improvements in quality and standards underpin the financial viability of glass recycling and enable recycling targets to be met. See section 3.1 for details of contaminants

2.2. Development of Alternative Markets

The development of new alternative as well as existing markets is also significantly increasing glass recycling in the UK. These include:

- Glass Manufacturing
- Blast Cleaning
- Filtration
- Construction Aggregates
- Fluxing Agent
- Decorative Aggregates
- Tiles & Ornamental Applications



The development of these markets has significantly increased competition in the marketplace for recycled glass making it increasingly commercially attractive to recycle. These markets have been supported by the introduction of new fiscal and regulatory drivers to the UK.

2.3. Legislative pressures influencing glass markets

Currently, there are four main legislative pressures that are driving the increase in the use of recycled glass

- Landfill tax
- European Community Directive on Packaging and Packaging Waste

[1] Envirowise GG83 guide 'Improving Cullet Quality'

- Climate Change Levy
- Statutory recycling targets
- The Pollution Prevention and Control (PPC) Regulations
- WEEE & ELV Directives

Landfill Tax

Despite landfill being the final step within the waste hierarchy, it continues to be the dominant method of waste disposal in the UK with 85% of the 30 million tonnes of municipal household waste being landfilled each year[1]. The Landfill Tax, introduced in October 1996, was the UK's first "green tax". Every time refuse is disposed of in a landfill site, the site operator must pay a tax contribution to H.M Custom and Excise. The aim of the tax is to take into account the environmental costs of landfill as a waste disposal method. For Local Authorities, if effective recycling schemes are implemented and the amount of waste going to landfill is reduced, this tax burden is lower and considerable savings can be realised. At present the landfill tax stands at £14 per tonne, however the government is committed to increasing this by £1 per tonne till 2005/06 when it will be increased to £3 per tonne each year thereafter till it reaches a mid-term price of £35 per tonne.

European Community Directive on Packaging and Packaging Waste

The Packaging Recovery Note (PRN) system was established in an effort to meet the requirements of the European Community directive on Packaging and Packaging Waste which required member states, including the UK, to bring legislation into force to achieve certain targets for the recovery and recycling of packaging waste The UK seeks to meet the requirements of this directive by introducing the Producer Responsibility Obligations (Packaging Waste) Regulations 1997. These regulations are enforced by the Scottish Environmental Protection Agency (SEPA) in Scotland.

The PRN system is a major incentive for container glass recycling since container glass falls within the scope of the packaging regulations. This means that when a re-processor recycles a tonne of glass they are entitled to issue a PRN that has a commercial value, although there are regulations concerning how this money can be spent. Figure 1 below shows recent PRN values for container glass.[2]

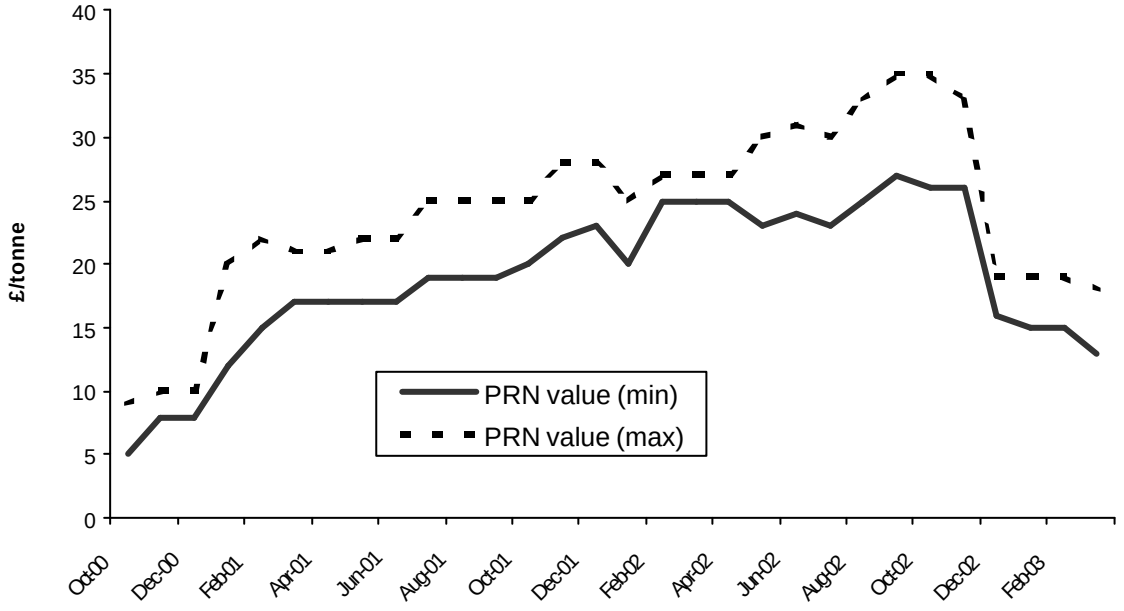


Figure 1: PRN values £/tonne of container glass

Businesses are obliged to comply with these regulations if they handle more than 50 tonnes of packaging per year and have a turnover greater than £2m. To comply with the Regulations companies must register and recycle a specified amount of their packaging waste.

[1] D.E.T.R 2000
[2] Data from letsrecycle.com PRN archive

The PRN scheme makes container glass cullet a cost effective feedstock for glass manufacturers. For example, Superglass Insulation Ltd based in Stirling can use either flat or container cullet in manufacturing processes. However due to PRN revenue container cullet is the more attractive option even although flat glass contaminant levels are generally lower.

Climate Change Levy

At the Kyoto Summit on Climate Change in 1997, the EU signed up to an agreement to reduce greenhouse gas emissions by 8% on 1990 levels by the year 2010. Although the UK's share was a commitment to reduce by 12.5% on 1990 levels by the year 2010, the Government set itself a domestic target to reduce emissions by 20% by the year 2010. To achieve this target, the Government introduced the Climate Change Levy with effect from April 2001. The levy is charged at a flat rate charged on each kWh of energy consumed by non-domestic customers who are not entitled to an exemption.

Given that glass manufacturing is a process with very high-energy requirements[1], the CCL has a huge financial implication for the glass industry, However, British Glass, which represents the glass manufacturing industry in the UK, is one of over forty trade associations with Climate Change Levy Agreements, which effectively reduces this tax burden. This agreement allows businesses that meet energy reduction targets to receive an 80% levy discount until the year 2013. Under this scheme, the UK glass industry has obtained a rebate on the CCL[2] providing it can achieve year on year energy savings amounting to a reduction of approximately 10% between 2000 and 2010. Without the rebate, the cost of the CCL to the industry would be £15m/year but the rebate limits the increase to around £2m/year.

One strategy encouraged to reduce energy requirements and meet these targets is the introduction of more recycled cullet in the glass making process as melting glass cullet requires less energy than producing glass from virgin raw materials.

The Integrated Pollution Prevention and Control Directive (IPPC)

The Integrated Pollution Prevention and Control (IPPC) Directive, due to be introduced in 2004, will set out targets within permit conditions to reduce pollution and emissions which glass companies will be required to meet. For aspects of an installation not regulated, permit conditions will be required to use Best Available Technologies (BAT) to prevent and reduce emissions.

Use of cullet in glass making will reduce CO_2 emissions from two sources. First, the reductions in energy requirements associated with increase use of glass cullet in furnaces will produce similar reductions in gaseous emissions such as CO_2 from the burning of fossil fuels. Second, melting cullet glass instead of using virgin raw materials will avoid CO_2 produced from the thermal degradation of raw materials containing carbonates such as soda ash, limestone and dolomite. It has been estimated that for every tonne of glass produced from virgin raw materials approximately 200 kg of CO_2 is released from the breakdown of carbonate raw materials[3]. Increased cullet use will also reduce particulate and nitrogen oxide emissions from the glass furnace.

[1] Energy Consumption Guide 27, The Glass Container Industry, 1997, ETSU
[2] See www.britglass.co.uk
[3] Recycled Glass Market Study & Standards Review, The Waste and Resources Action Programme (WRAP)

3. Technologies for maintaining cullet quality

3.1. The demand for improved cullet quality

Glass collected for recycling is often contaminated with a variety of unwanted materials. These contaminants can damage new products, alter its physical properties and reduce its saleability so processors such as glass manufacturers demand high quality, contaminant-free cullet from the glass processors.

However, once a contaminant has entered a batch the only solution is removal but efficient removal of contaminants is costly for the processors and may offset any financial benefits derived from the PRN scheme and any fuel savings. Naturally, glass manufacturers are reluctant to purchase poor quality cullet from processors and therefore reducing the level of contamination is essential to the financial viability of the glass recycling process. Table 1 below summarises typical glass manufacturer cullet quality standards[1] and the following section discusses the technologies available to achieve these standards.

Standard	Typical Limits	Typical Levels
Ferrous metals	<50 g/tonne	Clear 20-40 g/tonne Amber 20-35 g/tonne Green 20-35 g/tonne
Non-ferrous metals	<20 g/tonne	<1 g/tonne
Ceramics and stones	<20 g/tonne	Clear 20-40 g/tonne Amber 20-35 g/tonne Green 20-35 g/tonne
Organics	3,000 g/tonne	Clear 1,000-1,500 g/tonne Amber 1,000-1,800 g/tonne Green 1,200-1,800 g/tonne
Moisture	Shows no drainage	Shows no drainage (<2%)
Particle size	<50 mm	<50 mm

Principal Colour	Typical Limits	Typical Levels
Clear	Amber <2% Green <2%	Amber negligible Green 0.5%
Amber	Green <10% Clear <12%	Green 0-10% Clear 2-8%
Green	Amber <10% Clear <12%	Amber 0-10% Clear 0-10%

Table 1 Typical container glass manufacturer cullet quality standards

WRAP are currently developing a British Standards Institute Publicly Available Specification (BSI PAS) for raw cullet. These graded specifications will help stimulate differentiated market prices for different grades of material.

3.2. Types of contaminants

There are two broad sources of contamination,

- Inclusions, e.g. ceramics, masonry, TV screens, organic material and ferrous and non-ferrous metals.
- Glass of the wrong colour

Inclusions

Inclusions such as ceramics that are melted down with the glass change the appearance of the finished product and gas released by molten metal can produce bubbles in the final glass. In both cases the products will be rejected. Some contaminants damage the glass processing equipment resulting in higher maintenance costs,

[1] Wrap, Recycled glass markets study and standards review

e.g. metal items increase wear and tear on grinding and crushing equipment and ovenware items made from borosilicate (e.g. Pyrex) are difficult to detect in the raw cullet, melt at higher temperatures and as a consequence, block glass moulding machines.

Cullet derived from both flat glass and container glass can be used in a variety of end markets however container cullet is financially more attractive to markets such as container manufacturing due to the potential PRN revenue.

Fibreglass production can also use either container or flat cullet as a feedstock but again some manufacturers prefer to use container cullet in their manufacturing processes due to PRN revenue even though flat glass contamination levels are generally lower.

For flat glass the quality requirements are much higher than those for container glass. Chemical composition is critical for float glass production and the composition of the cullet must exactly match the glass composition in the furnace. To ensure these standards are met, flat glass manufacturers will often only recycle material that originates from their own processing plants.

A variety of new end markets and associated specifications have stimulated the introduction of several differing glass collection systems. The level of contamination can vary considerably in each system. Mixed colour collections have been introduced in some locations. However as the material is heavily contaminated with other colours it is only suitable for a few end markets. The majority of recycled glass remains to be source segregated and arises through the bottle bank system, kerbside schemes and civic amenity sites. This glass has the advantage of being suitable for a wide variety of end markets optimising its value.

As discussed earlier, recent legislation has exerted considerable pressure on the glass industry to use recycled glass cullet. However even with these pressures and the potential cost savings that using recycled glass can bring, manufacturers will avoid recycled cullet if they believe its use will result in an inferior product. Therefore, efforts to promote the use of recycled cullet must be matched by efforts to maintain high quality standards within the glass recycling industry.

Clearly, the starting point for solving the problem of cullet contamination is with the collectors and there are a number of low cost measures such as separation at source and public awareness campaigns that can be implemented by collectors to address this issue without greatly increasing collection costs. However once the contaminants are in the system, there are a variety of methods available to clean the cullet. Table 2 summarises these contaminants and their removal methods. More detail on these technologies can be found in the fact sheets that accompany this report.

Contaminant	Source	Clean-up technique	Fact sheet
Ferrous metal	Bottle lids and seals, iron, steel	**Electro-magnetic or permanent magnetic** devices installed on processing and conveying equipment	
Non-Ferrous metal	aluminium, brass, copper, lead	**Eddy current generation and detection**. Contaminant diverted from stream using pneumatic blast or mechanical diverting gate.	
Ceramics	Crockery, porcelain, ovenware e.g. Pyrex™, laboratory glass, cathode ray tubes from PCs or TVs, mirrors, lead crystal, light bulbs.	**Manual removal** using 2-inch screens. Larger items in waste stream are retained by screen and examined by trained personnel who pick out unwanted ceramics. **Automated ceramic removal** involves embedding fibre optic cables in a conveyer. The fibre optic emits pulses of light that pick out opaque material. Unwanted item diverted from stream with a pneumatic blast. **Size Reduction**: an alternative method to complete removal of ceramics is the size reduction of glass cullet to 12 mesh (1.7 mm) or smaller particles. This size reduction allows the ceramic	

		contaminants to melt in the furnace.
Organic	Paper and plastic labels and caps, cork, paper bags, wood debris, plants, food residue, textiles and any other hydrocarbon material	**Washing** Passing the cullet through a **size-specific screening device** **Burning out**.
Other inorganic	Bricks, concrete, stones, dirt, and dust.	Larger items can be removed using similar techniques to ceramic removal Dust and dirt particularly difficult to remove
Hazardous Waste	Medical or chemical refuse, needles and syringes; bottles and jars containing any liquid or solid hazardous or toxic material, coal or coal dust	**Manual removal** by trained personnel. Responsibility of collector

Table 2 Typical contaminants found in waste glass and their removal processes

Some manufacturing processes are more tolerant of contaminants than others. Table 3 below lists some common cullet applications and their tolerance for various contaminant types[1]

Application	Ferrous Metals	Non- Ferrous Metals	Ceramic	Organic
Glass Container Manufacturing	Not tolerated Risk of corrosion damage to the furnace and glass making equipment Melt but do not dissolve.	Not tolerated Risk of corrosion damage to the furnace and glass making equipment Melt but do not dissolve.	Must be free of large pieces of ceramics, Larger pieces of ceramic produce inclusions in finished glass containers	Too much organic material in the cullet can affect the oxidation state of the melt, requiring modifications in temperature control.
Fiberglass Insulation Manufacturing	As Above	As Above	Can clog fiberglass forming equipment	As Above
Art and Fused Glass	Low tolerance Aesthetics very important	Low tolerance Aesthetics very important	Low tolerance Aesthetics very important	Low tolerance Aesthetics very important May cause ash deposits
Portland Cement				Organic residue must be minimised, particularly

[1] Clean Washington Centre

Concrete				sugar. When mixed in PCC, sugar causes an increase in setting time, and a decrease in the strength of the final concrete.
Septic Treatment Filter Medium	Detrimental to effluent quality	Detrimental to effluent quality (e.g. lead)		It may be necessary to rinse cullet prior to use in filtration to minimize sources of biological degradation.
Aggregate Applications	Should generally have no more than 5% to 10% debris as determined using a visual inspection method	Should generally have no more than 5% to 10% debris as determined using a visual inspection method	Should generally have no more than 5% to 10% debris as determined using a visual inspection method	Decay of excess organics can cause potential settlement of the engineered fill.

Table 3 Common cullet applications and their tolerance for various contaminant types[1]

Colour contamination

One obvious problem is cross contamination from the different colours of container glass: clear, green and brown bottle banks are provided to try, with the public's co-operation, to keep the colours separate by pre-sorting the bottles. Maximum permissible cross-contamination is shown in table 4.

Cullet type	White flint (clear)	Amber (brown)	Green
Permitted contaminant	Amber (brown) 2%	Other colours 5%	Other colours 5% (exc blue)

Table 4 Maximum level of cross-colour contamination allowed[2]

However, some applications may have more demanding purity requirements and pre-sorting may not always be possible. Therefore, technologies have been developed to sort out the different colours of glass automatically.

Colour Sorting Technologies

The simplest approach to sorting glass into the three different colours is to request the co-operation of members of the public. However not all glass collection schemes request that the waste be sorted by colour prior to collection. For example bottle banks usually collect sorted colours, but kerbside programmes often collect unsorted bottles. If the bottles are not sorted prior to collection, the only option is for the collector to sort them prior to processing.

The effort invested in color sorting should be dictated by local market demand. In some cases it may be appropriate to concentrate efforts on the colour with the highest market value (usually clear), with the remainder being used for alternative applications such as construction aggregate.

[1] Clean Washington Centre

[2] Blue glass can be recycled with green but where there is a lot of blue glass, and concentrations in green are above 5%, suppliers are asked to contact the BGRC. Specifications criteria are supplied by: British Glass Recycling PO Box 6068, Edinburgh Way, HARLOW, Essex CM20 2UG, Tel: 01279 773 044 Fax: 01279 773 062 (fax)

Manual colour sorting is labour-intensive and only effective when glass particles are large enough to be handled this requires screening off and eliminating glass below 5cm in size which can account for up to 40% of the batch.

Automated colour sorting uses fibre optic or laser technology similar to that used to remove ceramic contaminants but with a different light source. The equipment should be programmed for the preferred colour removal. Automated systems can generally be configured to remove any one or a combination of the three glass colors. An unwanted item can be diverted from the waste stream with a pneumatic blast. These technologies must work with crushed glass to aid the removal system, and have traditionally been used to clean up the glass rather than completely colour segregate co-mingled glass into its colour streams, however these technologies have improved vastly in recent years and are now advancing towards equipment which can offer full segregation.

Moisture control

Recycled glass generally contains moisture from two main sources, original food content and dew and rainwater if the glass has been stored outdoors. When cullet is either too wet or too dry, processing and shipment can be difficult. Therefore, moisture control strategies may be necessary.

Not only does excess moisture in a batch of cullet represent a significant cost to customers buying by weight but also introduces technical difficulties, especially for fine sizing processes. High moisture content causes cullet particles to clump together and adhere to processing machinery. This can clog screening devices used for sizing and contaminant removal and also, since glass cullet is abrasive, can result in increased of wear of processing machinery. To avoid excessive moisture content, stockpiles of glass should be covered or stored inside prior to and during cullet processing. Dense clumps of fine cullet do not flow freely during loading and unloading of trucks and can clog loading gear and must be dried during the fine sizing process. However water can also be used to prevent clumping by washing the crushed glass through the sieves.

Drying Technology

Finely ground glass may retain moisture for years, especially if stored on an impermeable surface. In this case only movement and heat can dry finely crushed glass effectively. A typical dryer is an inclined tumbling rotary unit where the material tumbles by gravity from one end to the other as the unit turns. Heat is generated with a natural gas burner and air is blown through the unit with a fan. Dryers can also be paired with air cyclones to remove airborne dust during processing.

On the other hand cullet that is too dry will have very little cohesion and this too can cause handling problems and become difficult to stockpile. Dust control is also an important issue for dry cullet and it may be necessary to add moisture to the cullet. Dust can be controlled using measures discussed below. In general, fine-sized cullet powder should have moisture content of at least 0.2 to 0.3% to inhibit dust.

Dust Suppression Technologies and Techniques

All dusts create a nuisance within an operating environment, and prolonged worker exposure to high levels of dust can compromise workplace health and safety. Crystalline silica dust of respirable size (below 10 microns) can cause respiratory illness and long term health problems. Fortunately, glass dusts have been determined to be virtually free of crystalline silica, as the silica structure is converted to an amorphous state in the glass making process. Even so, dust from glass cullet can contain around 1% crystalline silica and up to 3% in respirable glass dust. This section will examine basic technologies and operating techniques to reduce the creation of fugitive dust.

There are several steps when glass processing that can generate levels of dust sufficient to exceed the limits imposed by health and safety standards. Dust suppression techniques or equipment should be put in place. Smaller granular size cullet requires more complex dust suppression techniques than does the primary process of producing the cullet.

4. Glass Processing Technologies

4.1. Glass Crushing Equipment

The purpose of glass crushing equipment is to reduce the glass containers into fragments of glass of consistent particle shape and size. The usual measure of particle size is through a sieve test, where the glass is sorted into those fragments small enough to pass through a sieve and those fragments retained on the sieve because they are too large to pass through the sieve. Standard sieve sizes can be found in Appendix 1.

Glass containers can prove to be a difficult material to crush into consistent particles while operating with speed and durability. Perhaps the most important aspect of selecting crushing equipment is matching the equipment with the desired capacity and finished particle size requirements, while minimising both capital and operating costs. However, there is a wide variety of glass crushing equipment on the market and in selecting the right equipment for a particular facility, it is important to know the anticipated volume of glass to be processed, the specific target end markets and the specifications required by those markets.

Container glass processing is similar in many respects to processing other aggregates, with two critical exceptions. Firstly, glass is lighter than other minerals and tends to bounce upon impact, rather than break. Secondly, glass shatters into fine particles which are extremely abrasive and which may enter the gears and bearings of traditional aggregate crushing equipment and cause serious damage. Thus it is important to identify equipment made to withstand the specific challenges that comes with the processing of glass. Manufacturers and suppliers of glass crushing equipment are listed in Appendix 2.

In its simplest terms, glass crushing is the process of feeding glass into a machine that uses rotating hammers, discs, and/or bars to crush the material. Some equipment can adjust the size of the finished cullet by adjusting the space between the discs and bars. Others achieve specific size reduction by continuous circulation of the cullet until it achieves the specified size.

Impact crushing equipment

Types of impact crushing equipment typically used in glass processing applications include**:**

- Rotating drums
- Hammer mills
- Vertical & horizontal shaft impactors
- Rotating disc and breaker bar

4.2. Glass Grains & Powders Products Line

Fine sizing glass containers to produce high quality granular products differs from cullet reprocessing predominantly in the area of size reduction. This is often done with two or more stage size reduction processes, although there are specific systems designed to process finely sized granular products with a single stage. Granular products are generally 2mm and smaller, with specific applications requiring sizing of 250 microns or smaller particles. UK suppliers of fine sizing equipment are listed in Appendix 3.

Two types of equipment often used to achieve granular glass:

- Vertical shaft impact grinder
- Flexible impact pulverizer

4.3. Conveyor Technologies

Glass cullet is an abrasive, hard and sharp material that can cause excessive wear and tear conveyors with the resulting high maintenance costs reducing profit margins. In addition, post-consumer cullet contains food residue and moisture, which can cause the cullet to stick to the conveyor surfaces.

Where glass is processed to fine grain and powder sizes technologies such as blowing systems may be more appropriate then a simple conveyor system.

Any conveyor system used in glass processing must be designed to handle these problems.

5. Meeting Specific Market Demands

There is a wide range of equipment available on the market (often modular) which can be modified to suit several end markets. It is therefore important when making purchasing decisions to consider the intended end market as well as more general factors such as throughput, cost and quality.

As previously discussed the largest market for recycled glass in the UK is the glass container sector which produces predominantly clear glass containers. However, the imbalance between the colours of glass imported into the UK and the glass manufactured has historically resulted in surplus volumes of green glass. This has prompted the development of alternative markets for recycled glass that can utilise all types and colours of glass.

It has been estimated that alternative markets for at least 600,000 tonnes per year of recycled glass need to be developed if a 70% recycle/recovery target for glass packaging is achieved[1]. Each of these markets will set their own specifications and standards for feedstock and so it is of paramount importance to choose equipment that will produce a cullet to end market requirements.

This next section reviews requirements for glass cullet markets and discusses factors that should be considered when producing cullet for different manufacturing processes. For a detailed discussion on market trends and scope for market development, see 'Wrap, Recycled glass markets study and standards review'.

5.1. Primary Markets

Primary glass recycling, as defined by WRAP[2] in their report 'Recycled glass markets study and standards review' is defined as re-melting glass and forming it into new products. Primary markets such as flat and container glass account for 80% of the 2.9 million tonnes produced by the UK glass manufacturing sector each year. Since glass recycled in this manner can be used over and over again, this is referred to as 'closed loop' recycling.

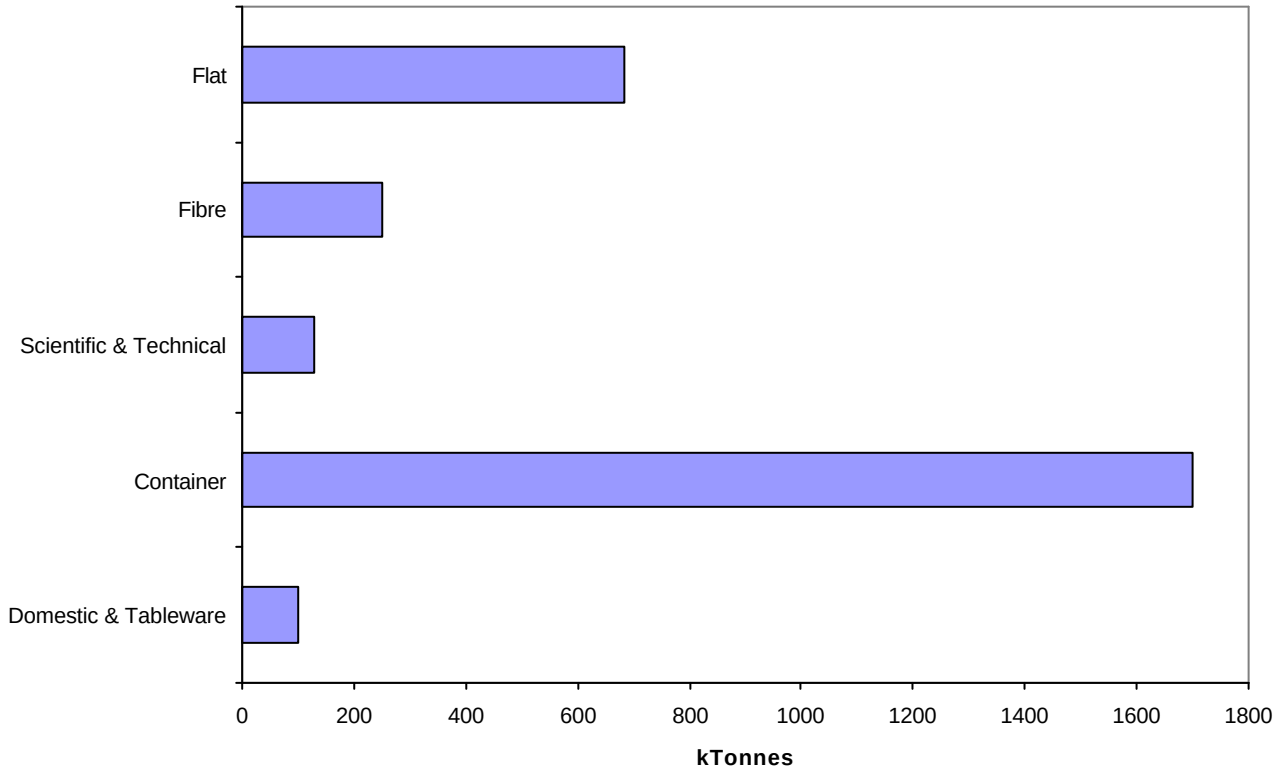


Figure 2: Glass Production (UK 2000)

[1] Wrap, Recycled glass markets study and standards review

Container Production

The main disadvantage using recycled cullet has over virgin raw materials is the introduction of impurities such as metal and ceramic etc as well as glass of the wrong colour. Particle size is also important with particles of around 20 mm preferred, as larger sizes cause handling problems and smaller sizes generate dust. Each glass manufacturer will set out their own set of specifications but typical specifications relating to these factors are shown in table 1 above.

Currently, the production of thin walled lightweight containers is preferred which imposes even more rigorous standards and even tighter colour uniformity is demanded.

Flat Glass Production

The quality specifications for flat glass are more rigorous than those for container glass. Table 6 gives the relative maximum 'seed count' for various types of glass, which indicates the number and size of gas bubbles in the finished product. Clearly container and fibreglass production tolerates a much higher seed count than the two flat glass application is quoted i.e. float and rolled plate. Table 7 shows the contamination levels tolerated in float glass. These are extremely stringent compared with those for container glass shown in Table 1.

Glass Type	Relative Maximum Seed Count
Float	1
Rolled Plate	7
Container	10,650
'E' Glass (reinforcement fibre)	25,000
Insulation Glass Fibre	50,000

Table 6: Relative Maximum Seed Count[1]

Contaminant	Float Cullet
Ferrous metal	Particles >0.5 g: none Particles <0.5 g: 2 g/tonne
Non-ferrous metals	Particles >0.1 g: none Particles <0.5 g: none
Ceramics/refractory Materials	No particles >0.2 mm
Organics	Particles >2 g: none Particles <2 g: 45 g/tonne

Table 7: Maximum Levels of Contaminants in Flat Cullet[2]

Similarly, it is critical that the chemical composition of glass cullet used in the manufacture of flat glass matches the glass composition in the furnace. To ensure this, many flat glass manufacturers will only recycle material that originates from their own processing plants and even then this internal cullet may only be used for rolled plate but not for float glass.

Glass Fibre Production

Insulation fibre manufacturers use significant quantities of external cullet but the quality requirements of continuous reinforcement fibre are too exacting to allow its use.

Ceramic contamination has been a particular problem with container cullet since larger pieces of ceramic can clog fiberglass-forming equipment. Also, in some manufacturing systems e.g. the cold top electric melting furnace operated by British Gypsum, (see Wrap, Recycled glass markets study and standards review) a cullet

[1] Wrap, Recycled glass markets study and standards review
[2] Pilkington cited within "Wrap, Recycled glass markets study and standards review"

with a low organic content is required since the organics volatilise giving rise to undesirable particulates and fumes. Generally, in a conventional fuel-fired furnace the combustion process destroys organic materials. British Gypsum therefore prefer plate cullet since it has less organic contamination than container cullet.

The PRN scheme makes container glass cullet a cost effective feedstock for glass insulation fibre manufacturers. For example, Superglass Insulation Ltd based in Stirling can use either flat or container cullet in manufacturing processes but due to PRN revenue, container cullet is a more attractive option even although flat glass contaminations levels are generally lower[1]. Superglass operates a conventional fuel-fired furnace, so either flat plate or container cullet is acceptable.

The cullet specifications for fibreglass production are similar to those for container glass (Table 1) accept:

Contaminant	Specification
Ceramic	Maximum of 30 g/tonne compared to 50 g/tonne for container glass.
Organic	Maximum of 120 g/tonne compared to 3,000 g/tonne for container glass.
Particle	Particle size <10 mm rather than <20 mm for container glass.
Colour	Mixed colour container cullet can be used if the mix is consistent. High levels of green and amber can interfere with heat transfer in the furnace and lead to poorer melting efficiency.

Table 8: Cullet specifications for fibreglass production

5.2. Alternative markets

Secondary markets, such as aggregates only involve a single use of the recycled product and are sometimes known as 'open loop' recycling

Several countries including the UK and USA have now tried and tested a variety of alternative markets for recycled glass which have proven to be both technically and financially feasible. Examples of alternative uses for glass are summarised in Table 9

Application	Substituted Material	Benefits of Recycled Glass
Aggregates – general fill	Natural aggregates	Lower cost Free draining
Aggregates – concrete	Natural aggregates	Lower cost Can increase strength of concrete Aesthetics
Aggregates – bound road sub-base	Natural aggregates	Lower cost
Aggregates – decorative	New application	
Water filtration	Sand / gravel	More efficient filtration
Shot blast abrasives	Metal slags Sand	Non-toxic Silica-free
Fluxing agent in bricks/ceramics	Mineral fluxes	Lower firing temperatures – energy saving.

Table 9: Principal Alternative Uses for Recycled Glass[2]

Other minor market alternatives include use as paint filler, a raw material for the production of zeolites, plant rooting medium, and art/craft applications.

[1] www..remade.org.uk
[2] WRAP, Recycled glass markets study and standards review

Aggregate

Each aggregate application feedstock must comply with specifications according to BS standard as well as general quality requirements. Key aggregate specifications are described below in table 10

Specification	Requirement	Standard
Grading	Sand particle size< 5mm	BS 812 Section 103
	Gravel particle size 5-70mm	
Flakiness	Measure of the particle shape.	BS 812 Section 105.1
	Generally, cuboid or rounded particle shapes are preferred.	
Shell Content	Not an issue with glass	
Mechanical Properties	Ten Percent Fines Value'	BS 812 Part 3: 1990
	Measure of the compressive force required to break down the aggregate.	
	Ten Percent Fines Value of 50 kN -150 kN depending on application	
Soluble minerals	Maximum acceptable soluble sulphate and chloride contents where the aggregate is in close proximity to concrete.	

Table 10: Key aggregate specifications

The main uses of aggregate in the UK include

- Highway construction e.g. general fill materials, bound and unbound road materials and structural concrete
- Concrete aggregate
- Decorative aggregates

Highway Construction: Almost half the UK aggregate production goes to highway construction and the specifications for all materials used in highway work in the UK are laid down in 'Specification for Highway Works'[1] also known as the 'White Book'. The guidance given in the White Book is very prescriptive and virtually every material has to conform to the relevant British Standard. The three principal uses use of aggregates are for general fill, road construction, and other concretes.

There is scope for introducing new materials in road construction but extensive monitored testing and trials are required. The Transport Research Laboratory (TRL) (or other independent organisation) carries out and scrutinises much of the testing. In all cases the new materials are compared to conventional materials to assess comparative performance. The cost of testing is financed by the manufacturer.

General Fill Materials

Part 2 of the White Book lays down the specifications for all fill materials. These include backfill for concrete structures, steel work, pipes and drains. These materials fall into nine categories:

For certain types of applications, only specific listed materials are allowed e.g. natural gravel, sand or crushed rock, and therefore there is no scope for using glass. Other applications only specify criteria such as grading, moisture content, 10% fines value or soluble minerals and so glass could be used as an alternative in many of the highway fill applications providing it meets the required performance specifications, however very little test data is available. Test data from the USA indicates that glass would be acceptable but ASTM standards are not directly comparable with BS/EN standards.

[1] Specification for Highway Works, vol 1-7, Department of Transport, HMSO

Bound and Unbound Road Materials

Roads are constructed in layers, starting with an unbound compacted layer upon which are laid bound courses and then a final macadam wearing course.

Unbound sub-base material may be 'crushed rock, crushed slag, crushed concrete or well-burnt non-plastic shale' and under current specifications glass is excluded.

BS 4987 and BS 594 layout specifications for bound base courses and wearing courses respectively. Glass cannot be used in wearing courses, as it does not have the required skid resistance but there are opportunities for glass use in the bound sub-base layers.

Structural Concrete

The White Book specifies that for concrete, the preferred aggregates according to BS 882 (natural aggregates) and BS 1047 (blast furnace slag) are recommended, although other aggregate can be used if specified by the engineer in charge of the project. However, glass is effectively excluded from this application under these recommendations.

Ready-mixed concrete has to be produced using BS 882 aggregates, which also excludes glass. British Standards for pre-cast products such as flags, kerbs, channels, etc. are generally performance based so possibilities for glass use exist.

Concrete Aggregate:

The major problem with the use of glass in cement is that the alkali in the cement can react with the silica in the glass ('alkali - silica reaction' (ASR)) to produce a gel on the surface of the aggregate that swells and can lead to cracks forming in the concrete. For this reason the concrete industry has avoided using glass as an aggregate, However, it may be possible to avoid ASR reactions[1], [2] by either using a fine sized glass aggregate, less than about 1 mm, or by suppressing the reaction with admixtures or using a low alkali cement. Other work has shown that with additions of very fine glass powder (<600 microns) the glass undergoes pozzolanic reactions, which have the potential to increase the concrete strength[3].

Advantages of using glass in concrete applications would include

- Very low water absorption and therefore improved durability
- Harder than most natural aggregates.
- Improved concrete flow properties and so higher-strength lower water mixes can be used.
- Very finely ground glass has pozzolanic properties contributing to the concrete strength.

However, currently, only aggregates specified in BS 882:1992 are used and since the specifications are for *natural* aggregates, this excludes glass. Therefore, glass will be excluded from ready mix concrete and pre-cast structural concrete both of which have to be produced using BS 882 aggregates. There may however be some scope to use glass in certain non-structural pre-cast products. These are also are produced to a number of BS specifications but the standards are performance-based rather than material based.

Type	Examples	Notes	British Standard
Architectural Cast Stone	Lintels, sills	Surface finish important fine aggregates used	BS 1217
Kerbs	Inc channels edges quadrants		BS 7263

[1] Meyer C, Egosi N and Andela C, 'Concrete With Waste Glass as an Aggregate', Recycling and Reuse of Glass Cullet Symposium, Dundee, 2001

[2] Meyer C, Egosi N and Andela C, 'Concrete With Waste Glass as an Aggregate', Recycling and Reuse of Glass Cullet Symposium, Dundee 2001

[3] Dyer TD, Dhir R K, 'Use of Glass Cullet as a Cement Component in Concrete', Recycling and Reuse of Glass Cullet Symposium, Dundee, 2001

Tiles	Fine aggregates used	BS 473
Blocks and Bricks	Blend of fine and coarse aggregates	BS 6073
Pavers	Fine aggregates used	BS 7263

Table 11 British Standards for pre-cast products[1]

Although glass cullet could meet these standards and be used in the manufacture of these products, there is considerable reluctance by manufacturers.

Decorative Aggregates:

Glass used as decorative mulch and landscaping aggregate is a crushed and graded product (usually < 20 mm) that has been 'tumbled' to remove sharp edges. There are no universally accepted standards or specifications for this product but Day Aggregates in London reprocess bottle bank glass to produce glass 'sharp paving sand' to BS 7533.

Glass for Sports Turf Applications:

The Sports Turf Research Institute (STRI) are considering the use of ground glass for three general purposes:

- Construction use – e.g. Golf courses where ground glass may be a suitable substitute for sand on green areas but the effect of the material on plant root abrasion will need to be studied.
- Bunkers – Angular material is preferred in bunkers as it aids stability. Clear glass may be preferred for visual impact.
- Earthworm control -Glass sand may be a suitable material for worm control.

Colour and size grading are specified by the STRI but there are no British Standards applicable to sand for sports and turf use. The most common particle size gradings are 0.125-0.5 mm and 0.25-0.75 mm.

Filtration

Crushed glass may be a potential granular media for water filtration applications such as the treatment of potable water, municipal wastewater and industrial wastewater providing it meets specifications for particle size distribution and quality.

There are three main types of granular filtration system

- Slow filtration where water passes through a large but shallow sand-bed by gravity.
- Rapid gravity filtration which also relies on gravity but can handle a greater flow
- Rapid pressure filters that force water through the sand-bed under pressure.

Efficient removal of particulate waste from the water flowing through the filter requires a filtration system composed of a granular material of an appropriate size. If the particles are too small, the media will be too compact with very little void space for the collection of the particulate waste and the resistance to water flow will be too high. If the media particles are too large, solids particles in the water will pass through.

Other filtration applications for recycled glass include

- Swimming pool filtration
- Aquaculture and fish farming applications

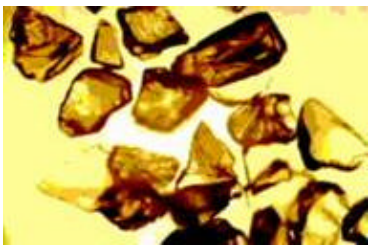
Work carried out by the Clean Washington Centre (CWC) demonstrated the potential for crushed recycled glass as a filtration media for slow rate filtration for certain water sources. Furthermore, CWC research suggests that on high-rate filtration, crushed glass performs to the same standard as conventional sand for swimming pool

[1] Wrap, Recycled Glass Market Study & Standards Review

filtration[1]. In Scotland, Dryden Aqua has supplied municipal swimming pools with AFM glass media and satisfactory results have been reported at all the installations.

Applications such as fish farming may require water treatment if it is to be recycled or if high purity is required. In this case glass filtration media may be a possible substitute for sand.

Standards and specifications



According to research carried out by Wrap[2], grain particle sizes range from 0.5 mm to 2.0 mm are acceptable for treating potable water, and up to 4.5 mm for waste water, depending on the filter application and the quality of the water to be treated. Other specifications include:

- Angularity
- High abrasion resistance to avoid grains being crushed during the backwash cycle.
- Freedom from organic contaminants
- Supplied ready-washed.

Treatment of potable water

Drinking Water Inspectorate (DWI)

In the UK, there are strict specifications governed by the Drinking Water Inspectorate (DWI) that regulate the use of products for the treatment of drinking water. Before the DWI Committee on Products and Processes (CPP) specifies its test requirements a BS 6920 test report, or equivalent European test report must be supplied. The CPP also requires the following information

- Chemical composition of the product
- Method of manufacture
- Its intended use
- Instructions for use
- Leachate analyses may also be required to identify toxic substances. This analysis will be conducted under the guidance of the CPP.

For approval to be granted, the DWI Committee on Products and Processes must be satisfied that the use of the product will have no adverse effects on either public health or water quality. BS EN 12904:1999 lays out standards for silica sand and silica gravel filtration media but BS EN 12904 specifies a minimum silica content of 80% by weight whereas the silica content of recycled glass is around 74%, and therefore is not covered by this British Standard. To gain approval by the DWI extensive testing will be required and the minimum timescale for approval is nine months. At present Dryden Aqua are trying to gain 'Regulation 25' accreditation for their Advanced Filtration Media (AFM) product. However each producer of glass filtration media for drinking water will be required to go through this system and have their process and media accredited by the DWI.

Water Byelaws Scheme

The Water Byelaws Scheme governs the testing and approval of fittings and materials used within the water consumer's installation i.e. when drinking water is in contact with the product after it has left the water undertakers' pipes. The WRC Evaluation and Testing Centre is responsible for carrying out tests to establish whether the product satisfies the water byelaws. Non-metallic materials, e.g. a crushed glass filtration media, are tested for compliance with BS 6920:1990, for the suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of water.

Regulation 25

This regulation stipulates that substances and products that will come into contact with public water supplies must be approved by the Secretary of State unless they are already approved under a former voluntary

[1] "Evaluation of Recycled Crushed Sand Media for High-Rate Sand Filtration", CWC Guidance (http:// www.cwc.org)
[2] Wrap, Recycled Glass Market Study & Standards Review

approval scheme, fall within the scope of Regulation 25(1)(b) or (c) or are to be used solely for testing and research.

Regulation 25(1)(b) allows the use of an unapproved product where the surface areas in contact with water is small and Regulation 25(1)(c) allows the continued use of products which were in use prior to the introduction of the statutory approval system on 1 September 1989.

Wastewater

The advantage of using crushed glass media over sand as a fine media filtration for industrial wastewater treatment is that fouling is less of a problem due to the smooth surface of glass. Furthermore, surface catalysts in the glass such as ferric oxide from amber glass and chromium dioxide from green glass, may improve the efficiency of the treatment process[1].

However pressure systems for new installations are becoming more popular and this trend may reduce the potential market for glass since a pressure filter requires about a tenth of the media required by the equivalent gravity system. However, if this is the case, and glass performs better than conventional media, it may command a higher price.

Blast Abrasives

Blast cleaning involves firing a granular or powdered abrasive at a surface such as metal using high-pressure air or water and is used to clean and prepare the surface for painting. Abrasives can be either expendable which are generally for single pass usage or non-expendable which can be reused many times before becoming spent.

Non-expendable abrasives are expensive high quality materials and include alumina, silicon carbide and steel shot. These materials are generally used indoors in closed booths, expendable abrasives are used for on-site cleaning, such as structural steel work e.g. bridges. Expendable abrasives are much cheaper than recyclable abrasives and include metal slags, garnet, sand and copper slag (e.g. 'J-Blast'). In addition to the cost of the abrasive, the following factors must be taken into account:

- The cleaning rate (i.e. m^2/hour cleaned) since labour costs are often the largest component of a job.
- Consumption rate of the abrasive (kg/m^2 of cleaned substrate).
- Disposal costs of spent abrasive.
- Skill of operator.

There have been two recent studies comparing the performance of crushed glass with copper slag. This work was carried out by the Clean Washington Centre in 1997[2] and confirmed by REMADE Scotland[3]. Consumption rates, cleaning rates and breakdown characteristics of the abrasives when cleaning a variety of coatings off steel and aluminium were studied. In general glass performed as well as copper slag and, in some situations, slightly better.

All aspects of the blast cleaning operation are covered by BS EN ISO 44427/BS 7079, and common abrasives (copper slag, garnet, nickel slag, aluminium oxide, etc.) are specified in the standard. However, the fact that glass is not mentioned in the standard is not necessarily a barrier to its use as an abrasive since it is only the cleaned surface of the steelwork that is important in terms of surface profile (roughness) and general cleanliness.

In some cases, copper slag waste is classified as special waste, which increases the disposal costs and in addition, it cannot be used in environmentally sensitive areas due to the risk of contaminating watercourses. This is due to the significant heavy metal content (copper, nickel and lead). The use of sand poses significant health risks when used in dry blast situations since air borne crystalline silica can cause silicosis. Glass contains less than 1% crystalline silica and poses no such similar risks.

Table 12 below, shows typical size and contaminant specifications for blast abrasives. Note that these contaminant levels are very similar to container cullet.

[1] Wrap, Recycled Glass Market Study & Standards Review
[2] 'Testing and Certification of Industrial Abrasives Manufactured from Recycled Glass', CWC, 1998
[3] www..remade.org.uk

Typical particle range[1]	Size range
Coarse	1.0 – 3.0 mm
Medium	0.75 - 1.0 mm
Fine	<0.75 mm

Contaminants	Maximum levels
Ferrous metals	0.005% (50 g/tonne)
Non-ferrous metals	0.002% (20 g/tonne)
Organics	0.05% (500 g/tonne)
Ceramics	0.005% (50 g/tonne)

Table 12: Typical specifications for blast abrasives

Bricks & Ceramics

Bricks

Bricks cost approximately £35/tonne to manufacture and of this total, raw materials cost £5 and energy £11. The main raw material is clay, which is often quarried on-site and other minor additions include sand, stains and other minerals.

Plate and container glasses contain around 15% Na_2O and when finely ground and heated will soften and fuse at around 1000°C. Finely ground glass mixed with clay acts as a 'flux' and bonds to the clay. When finely ground glass is mixed with brick-making clay, the firing temperature can be reduced during the brick-making process, thus saving energy and reducing fuel costs. The final product is a stronger, more frost-resistant brick[2] and, in addition, glass may also reduce hydrogen fluoride (HF) emissions. This will help brick manufacturers to meet IPPC regulations, which will require most brick kilns to be equipped with HF abatement equipment resulting in increases in running and capital costs. Despite these advantages, brick makers rarely use glass but now, since the brick industry is subject to Climate Change Levy, there has been renewed interest and currently there is a research project involving CERAM, the major UK Brick companies and Glass Recycling Systems Ltd.

Specifications for the Glass

General specifications for glass cullet for use in brick manufacturing are shown in table 13. Costs of grinding to the required specification will be high and the insufficient fine grinding capacity in the UK may prove to be a barrier to accessing this market but current processing operations can easily meet the tolerated contamination levels.

[1] Wolverhampton Greenblast
[2] General Information Leaflet 29, Use of Waste materials in Clay Brick Manufacture, ETSU, 1993

Specification	Requirement
Particle size	<75 μm. Ball milling will be required to achieve this degree of fineness. Dust containment will be required
Chemical composition	Tolerant to both plate and container glass
Colour	Any
Organic contaminants	<1%
Metal contaminants	0.5%

Table 13 General specifications for glass cullet used in brick making

Other Ceramic Applications

Pottery manufacturers use minerals such as nephaline syenite and feldspar as a fluxing agent to bind clay and other fillers together during firing. These minerals make up about 25% of the 'body' and it is their Na_2O and K_2O that account for their fluxing action. The Clean Washington Centre (CWC) carried out trials using 100 and 250 μm glass and obtained encouraging results but further work is required. Similarly ground glass can also be used as a component of pottery glazes to provide a source of Na_2O and K_2O.

Specifications

Specifications for the pottery and pottery glazes market are likely to be more rigorous than for brick manufacturing and extensive work will be required to establish the acceptable purity levels for the glass.

6. Overview

6.1. Overview

The use of recycled glass products can be beneficial to several large market sectors including glass manufacturing, water filtration, blast cleaning and ceramic / brick manufacturing. These advantages relate mainly to reduced raw materials costs and energy savings, and in many cases can outperform traditional materials. However, quality remains a considerable barrier to a number of some markets but for others such as the glass manufacturing and fibreglass sectors the benefits can outweigh the risks.

In recent years legislative pressures have made the use of glass cullet more attractive and have greatly influenced the UK market for recycled glass. Coupled with the increasing cost of landfill the Packaging Recovery Note (PRN) system has made recycled glass economically attractive and the Climate Change Levy has made the lower energy requirements of using glass cullet as a raw material in place of virgin raw materials a key factor in reaching industry targets for reducing energy consumption. Similarly, the Integrated Pollution Prevention and Control (IPPC) Directive, due to be introduced in 2004, will set out targets to reduce pollution which glass companies will be required to meet and again increasing the amount of recycled cullet will assist the industry in meeting these targets. However, in the long-term, these pressures can only influence the market for recycled glass if the products are of sufficient quality to meet customer demands.

These drivers as well as increasing public demand for recycling will clearly drive glass recycling forward in the UK. With greater penetration into the various waste streams yielding greater volumes of recycled glass it is essential that the alternative markets for recycled glass products continue to be developed. These markets will set their own market specifications which will invariably set the challenge to glass processors. Technologies which have advanced considerably in recent years will need to continue to develop to keep up with this rapidly advancing industry.

6.2. UK Market Development Network

The UK Market Development Network is a group of regional programmes that share the common aim of developing markets for recyclate materials. Each programme works with both the commercial and public sectors to stimulate and support both new and historical markets for recyclate materials.

This is done through working with specific material supply chains, using an integrated approach and ensuring there is no unnecessary duplication of research. Dissemination of work and identification of best practice have been key to engage commercial enterprise.

All members of the UK Market Development Network can be contacted regarding both regional and national recyclate market issues. They include:

ReMaDe Scotland

ReMaDe London

ReMaDe Essex

ReMaDe Kernow

ReMaDe South West Ltd

ReMaDe Kent and Medway

Waste & Resources Action Programme (WRAP)

Clean Merseyside Centre

Hampshire County Council

Wales Environment Trust

Enviros

Urban Mines

Contact details for all organisations listed above can be found in appendix 3.

7. Technology Hand Sheets

This section of the handbook will briefly look at each of the various types of equipment included in glass processing and give a quick insight into what factors should be considered when selecting a particular item.

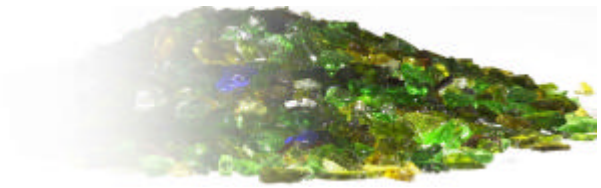
The format of this section will be a series of hand sheets and is designed for easy access to the particular topic of interest.

A list of contact details for each company mentioned is available in appendix 2.

It should be noted that the inclusion of companies in this report does not mean, or imply, any endorsement by Remade Scotland of these organisations, their products or services they supply. This document is intended to be used as an introduction to which factors should be considered when purchasing equipment for processing glass and a selection of suitable vendors. For further technical information on any pieces of equipment please contact the vendors direct.

The selection of companies mentioned in this report is not a definitive list and we are aware that other glass equipment vendors may exist. However, through time we aim to develop as comprehensive a list as possible and welcome your input. Therefore, if you are aware of a company that you feel should be included, or have any comments please feel free to contact us.

Photographs on hand sheet headingswere kindly supplied by Krysteline



Crushing Equipment Types & Sizes

Key Issues:

Container glass is a hard abrasive material requiring in some cases several processing stages to produce a consistent particle size and shape suitable for a variety of end markets. Factors such as degree of contamination, throughput and available technology can all have an impact when processing glass. However, advances in technology are increasing opportunities to maximise the potential of this valuable resource.

Perhaps the most important criteria in selecting crushing equipment is matching the best technology with the feedstock to produce the desired end product, whilst minimising both capital and operating costs.

Introduction

In its simplest form glass crushing is the process of feeding glass into a machine that typically with the use of rotating hammers, discs, and/or bars size reduces the glass feedstock.

Glass processing is similar in many respects to processing traditional aggregates, with a couple of critical exceptions. Firstly, glass is extremely lightweight compared to other minerals and tends to bounce upon impact rather than simply break. Secondly, glass shatters in to fines which are angular to sub-angular and extremely abrasive. These fines can potentially have an adverse affect the bearings and other sensitive sections of traditional aggregates crushing equipment, causing equipment damage.

Particle size, one of the most important criteria to end markets can be adjusted in many technologies by changing the space between the discs and bars or by altering the throughput speed. Others achieve specific size reduction by continuous circulation of the cullet until it achieves the specified size. This is an important factor when deciding if the system will process glass to meet one principal end market or several.

It is important to identify equipment which can cope with the unique characteristics recycled glass possesses the challenges it brings.

Types of impact crushing equipment typically used in glass processing applications include**, rotating drums, hammer mills and vertical shaft impactors.**

Rotating drums - This type of equipment typically has a spinning rotor with bars attached to the outside. The rotating bars impact the glass, sending it against breaker plates mounted on the inside of the exterior walls. The material continues to impact until the required particle size is achieved where upon it will fall between the space between the rotating bar and the plates. This space can be adjusted in order to adjust the size of the finished cullet.

Hammer mills - A shaft rotating at relatively high speed with movable hammers attached propels the glass to the side of the chamber, as well as against other glass. The glass continues to re-circulate until it has achieved the appropriate size reduction to pass through the screening system. Relatively small sizes glass grain can be achieved; however this has an incremental effect on the wear rate of the hammers.

Vertical Shaft Impactor (VSI) - Glass is fed into the top of the system and flung against the walls of a size reduction chamber by a revolving cylindrical rotor. The glass is

broken down by the continuous bombardment of other glass particles and consequently the wear on the moving parts of the VSI is minimised. When the glass has reached the desired size it passes through the screening system. These devices are typically used in large scale, high throughput glass processing applications.

Most V.S.I.'s will require a pre broken feedstock. This can be achieved by primary crushing with a very basic hammer mill.

Horizontal Shaft Impactor – or simply Impact Crusher uses a continuous breaker bar which is mounted horizontally in the rotor and material is thrown against either one or normally two adjustable aprons. The unit is lined throughout with replaceable liners, the end product passing an open discharge. This type of unit produces a high volume throughput of product from 10mm minus from whole bottles with an angular to sub-angular particle shape, produced from the particle on particle bombardment, but not to the degree of roundness achieved with a V.S.I.

WRAP are currently funding research looking at the viability of using Vortex Grinders for processing glass, and results are due in early autumn 2003. For further information regarding this research please visit the WRAP website at: www.wrap.org.uk

The wear rate of any replacement parts such as breaker bars or hammers is also an important factor when selecting a technology as this can greatly affect the operating costs and downtime of the process.

When selecting processing equipment it is important to understand the following:

- Throughput, feedstock and desired end market
- Is the equipment modular i.e. can other pieces of equipment be added to it?
- Is the equipment mobile or static?
- No. of operators required?
- Technical support available
- Budget, Operating costs

It is important when selecting any type of equipment that it should be verified by testing, as to capacity, the power and crusher speed as these can be varied, (creating different characteristics from initial feed material size) and particularly wear rates, which in some cases can be excessive. Also variation in particle size expressed as % passing is probably equally as important for some products as actual particle shape, but again dependant upon requirement of the end market and both tonnage required against available raw material.

Auxiliary Equipment - Other pieces of equipment such as, conveyors, screens, magnets, eddy current, dust control, colour sort, ceramic removal can compliment crushing technologies increasing the quality of the final product, however these will be discussed in more detail later in the report.

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Small-Scale or Mobile Processing Equipment

Key Issues:

Small-scale or mobile processing may be set up to serve a variety of purposes. Most commonly these systems are used in rural areas where high transportation costs can make it uneconomical to transport the glass to principal glass markets. It is also suitable where only small volumes of glass need to be processed. These circumstances often encourage the development of local markets for recycled glass.

Mobile processing systems can be advantageous where sources of glass can be stockpiled and processed periodically when necessary. Mobile systems can also be utilised by several communities thereby spreading equipment costs.

Introduction:

In determining the best solution for small-scale processing operations the processor should:

- Determine both current and future recycled glass arisings
- Identify local end markets and associated specifications
- Identify the sustainability of end markets
- Identify equipment suitable for achieving end market specifications

As with most glass processing operations, markets must be found for all particle sizes being generated by the system. Oversize material can be fed back through the system; however markets must be available which can utililse the finer sized material.

Small-scale processing systems can provide local solutions to local problems whilst generating local jobs.

Many small-scale glass processing technologies can be bought off-the-self from specialist vendors. Traditional aggregates crushing systems have also been adapted by some processors to handle recycled glass.

Some equipment vendors are beginning to offer partnerships with processors and collectors rather then simply selling the equipment. This has the benefit of sharing the cost and risk of the venture, whilst utilising the full technical expertise of the equipment vendor and continued customer support.

There are many primary size reduction technologies available which are designed to improve transportation efficiency; however these must not be mistaken for systems designed to fine size glass.

Glass can be processed locally to meet several alternative markets such as:

- Construction aggregate
- Shot-blasting
- Decorative applications
- Filtration

Traditionally glass recycling has been on a large-scale by specialist processors supplying it back into the glass manufacturing industry; however the emergence of new alternative

markets and improvements in technology have increased the opportunity to economically process glass on a smaller scale.

Equipment Vendors:

Andela	BJD Processing	BL-Pegson Ltd
Prodeva	GAME	
Christy Hunt	Magco Tollmache Ltd	
Donico	American Pulverizer Company	
Krysteline	Lightning Crushers	
C.S.Bell	Pulverisers & Shredders Ltd	

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Mid-size Glass Cullet Processing

Key Issues:

Mid-size aggregates processing lines are typically set-up to process large volumes of glass at a low cost. These systems may be set-up with existing rock or concrete aggregates processing equipment, or may be designed as stand alone glass processing systems. This type of system can vary considerably in size, capacity and cost.

Introduction

Many local authorities are currently using recycled glass as a substitute for aggregate in a variety of end uses. These include:

- Base / sub-base
- Embankments
- Utility bedding
- Retaining walls
- Drainage

With a vast number of potential aggregates applications suitable for crushed glass the specifications for each can vary considerably. Crushing technologies can typically be complimented with screening and other contamination removal technologies where necessary. Crushing technologies used include primary impact crushers or similar type equipment.

Several companies in the UK are now processing recycled glass using conventional aggregate crushing technologies, however glass cullet is light-weight and highly abrasive compared to conventional aggregate material and as such can potentially cause excessive wear / damage to sensitive areas of equipment such as the bearings. Trials should be done early on in the process to ensure equipment is suited to the unique dynamics of processing glass.

Technologies suitable for crushing glass into cullet for aggregate applications include hammermills, impact crushers, rotating drums and breaker plates. Several equipment vendors have now introduced technologies to the markets for processing recycled glass. These technologies have typically evolved from traditional aggregates crushing systems.

In determining the appropriate equipment the user must consider both the volume of glass to be processed, the end market specifications and if any of these factors will change in the future.

In addition to the basic crushing equipment, feed hoppers, conveyors, and screening may be desired, which will increase the capital costs.

List of Equipment Vendors

Magco Tollemache
BJD Processing
BL-Pegson Ltd
Christy Hunt
Lightning Crushers
JE Crusher services (UK)
Pulverisers & Shredders Ltd
American Pulveriser Company
Williams

Contacts:

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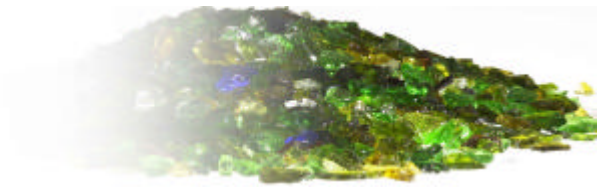

Producing Glass Grain

Key Issues:

Fine sizing glass to produce high value granular products differs from cullet reprocessing as high value products generally require the glass to be sand-size. This is often done with two or more stages of size reduction. However there are specific systems designed to process finely sized granular products with a single size reduction. Granular products are generally 2mm and smaller.

Another reason for fine sizing is to reduce the size of ceramic particles and other contaminants present in the feedstock, which can potentially cause inclusions and areas of weakness when used for glass manufacturing. By reducing the size of the feedstock to a point where ceramics and other contaminants are able to melt in the furnace can reduce the risk caused by contaminants. However a downside to this is that smaller particles can tend to 'dust' in the furnace.

Introduction

When trying to process glass to a fine size the following should be considered:

- Condition of glass (complete bottles, fragments, cullet)
- Throughput
- Target end markets & associated specifications
- Organic residue present
- Ancillary equipment required
- Appropriate sieving technology

Where glass is in the form of bottles or large fragments a preliminary size reduction stage is often necessary. This is usually performed using a simple breaker which will reduce the size of the glass as well as releasing contaminants such as labels and caps from the glass. The cullet will then generally go through a series of contamination removal stages. It will then go on to the pulverizer stage where the final size reduction takes place and possibly further contaminant removal.

Two types of equipment often used to achieve fine-sizing of glass cullet are **Vertical Shaft Impactors (VSI)**, and **Flexible Impact Pulverizers (FIP).**

How the Technology Works:

Vertical Shaft Impact Grinders – In a vertical shaft grinder (VSG) unprocessed glass cullet is fed into a chamber with the spinning rotor. The rotor accelerates the cullet into a size reduction chamber where particle-to-particle bombardment reduces the particle size. By using a strategy of particle-to-particle breakdown wear on equipment parts is reduced.

Fine sized particles are screened off and coarser particles are re-circulated through the VSG until they have been sufficiently reduced in size. VSG equipment can be adjusted to produce various size materials ranging down to approximately 1.7 – 0.425mm.

Certain materials (usually contaminants) will not break down to 1.7mm in size or smaller and will tend to build-up in the chamber of the equipment. Periodic removal of this contamination is required to maintain the efficiency of the system.

Flexible Impact Pulverizers - Flexible impact pulverizers (FIP's) achieve size reduction by impacting the cullet with rotating hammers as well as particle-to-particle bombardment.

In this system cullet is fed into the first of two horizontal chambers. Each chamber has a series of impactors mounted on rotating belts. Cullet is moved through the chamber by the impact of these impact hammers. As the cullet moves through each chamber, it is reduced in size both from the impact of the hammers and also the collision with other glass particles. Once the glass has passed through the second chamber, it is screened by a rotating trommel which separates out the fine-sized pieces.

The FIP equipment is typically used for smaller scale operations and for preparing glass for markets that do not require the extremely fine sized materials.

Other technologies are now beginning to enter the marketplace for fine sizing glass such as high speed implosion systems.

Adjusting Particle Size

As with many size reduction technologies the final particle size can often be adjusted by simply reducing the speed of the input feedstock or by increasing the residual time the glass spends in the processing chamber.

It should be noted as a general rule that the smaller the particle size the higher the processing costs.

Moisture Control

With many medium to high value markets one of the most important specification criteria is particle size, which is why the presence of organic residue or moisture in the feedstock can prove very problematic. These residues have the potential to cause particles to clump together, significantly reducing the efficiency of screening technologies.

Ideally if the residue/moisture content of the feedstock appears high, the material should be washed and dried before it reaches the sieving stage. However, too little moisture can also cause problems with dust. Moisture control techniques will be discussed in more depth in later sections.

Fine-Sizing Equipment Available in the UK

Traditionally glass crushing equipment used in the UK has been derived from traditional aggregates crushing systems. However in recent years glass specific processing equipment vendors have introduced their technologies to the UK market, enabling processors to purchase 'off-the-shelf' specialist technologies.

Equipment Vendors:

Andela	Donico	BL-Pegson Ltd
Prodeva	GAME	BJD Processing
GRTF / Minpro	Christy Hunt	Magco Tollmache Ltd
Hazemag	American Pulverizer Company	EME
Krysteline	Lightning Crushers	
C.S.Bell	Pulverisers & Shredders Ltd	

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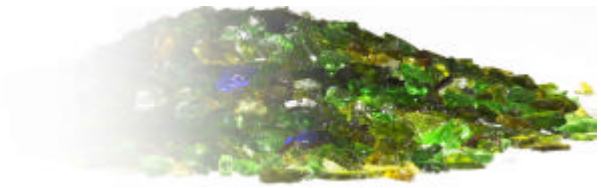

Dry Milling of Glass

Key Issues:

There are developing markets for grades of glass powder that are somewhat finer than can be achieved using the equipment described in the "fine sizing" section of this manual. These "fine milled" products can be produced using a range of established milling techniques.

The milling equipment employed for the processing of glass is generally similar to that utilised when handling hard, abrasive minerals such as quartz, feldspar, bauxite etc.

Where there is a need for a closely controlled particle size distribution (p.s.d.) and/or topsize then air classification is often used in conjunction with the milling process.

Typical product specifications for fine milled glass products include 90% minus 250 micron, 90% minus 150 micron, 90, 95 and 99% minus 75 micron, 97% minus 63 micron and 99% minus 45 micron. Should markets become established for finer grades of milled glass than ultrafine milling technology from the industrial minerals sector can be employed to achieve this.

Generally speaking, the finer the product the more sophisticated the application, the more exacting the specification and the higher it's value. However, the finer the product the less likely that any contamination can be tolerated so highly efficient contamination removal systems need to be employed.

By their very nature, fine milled glass products are dusty so nuisance dust suppression and collection systems are essential, as is the case in any mineral milling system.

Introduction

When milling glass to a fine size the following should be considered:

- Condition of glass (complete bottles, fragments, cullet)
- Throughput
- Target end markets & associated specifications
- Organic residue present
- Moisture Content of Glass
- Necessity for sieving and/or air classification to achieve fineness requirements

Where glass is in the form of bottles or large fragments a preliminary size reduction stage is always necessary. The type and size of the milling equipment will dictate the size of feed material required. As a general rule for fine milling the finer the feed material the better.

The Available Technology:

Ball Mills – When handling tough abrasive materials such as glass cullet the ball mill is the technology most widely employed. The ball mill can be designed for either "batch" or "continuous" operation and consists a cylindrical shell that is normally provided with a wear protective lining. The mill is "charged" with a combination of glass cullet and grinding media which is typically hardened steel or ceramic balls and is

rotated around it's axis at a speed which causes the charge to "cascade". Size reduction results as a result of impact and attrition within the mill charge.

Depending on the application for product the end-user will dictate whether a small amount of iron contamination can be tolerated or not.

Where iron contamination is not an issue the mill is normally lined with replaceable alloy steel liner plates that are bolted through the mill shell. Hardened steel balls are used as the grinding media.

When iron pick-up from the milling process is an issue - in ceramics for example, the mill is typically lined with either silex (silica blocks) or aluminium oxide bricks. Grinding media is normally aluminium oxide or flint pebbles.

In a "batch" mill the machine is charged with material and media and then operated for the period necessary to reach the required particle fineness. The mill is then discharged and the product separated from the grinding media. Batch mills are considered to be labour intensive and are most commonly employed where capacity is relatively low.

Continuous ball mills are normally employed when higher throughputs are required. In the processing of industrial minerals ball mills with installed powers of greater than 500 kW are not uncommon. In cement processing, where ball mills are also employed, machines with installed powers of over 1 MW provide "economies of scale" offering very high throughputs at reduced operating costs.

A continuous ball mill can be operated either "open circuit" where the residence time of the material in the mill determines the product fineness or in "closed circuit" with a separation device such as a screen or an air classifier where fine product is discharged from the system whilst oversize returns to the mill for further size reduction. When control of the p.s.d. and/or product topsize is required closed circuit is the preferred method of operation.

Moisture Control

As a general rule the maximum moisture content for a dry ball milling process is approximately 1%. This often necessitates a pre-drying step in the process - normally following crushing and the removal of contamination. The exception is when an airswept ball mill is employed in which hot gas passes through the mill and can be utilised for the simultaneous drying and grinding of the glass.

Where air classification or screening is required to control the p.s.d. and/or product topsize the milled product has to be to all intents dry.

Alternative Mill Technologies

Other milling technologies that are traditionally used for the processing of industrial minerals but could be applied to the grinding of glass include:

- Table-Roller Mills
- High Compression Roller Mills
- Fluidised Bed Jet Mills

Table-Roller Mills – Traditionally used for the processing of industrial minerals such as calcium carbonate, barites, gypsum etc. Also used in Power Stations for coal. Material is fed to the centre of a rotating grinding table where centrifugal action moves the material outwards and into the path of 2 or 3 grinding rollers that are spring or hydraulically loaded. A bed of material is built up between the grinding rollers and the

table and size reduction occurs as a result of crushing and attrition. The ground material is carried upwards in an air stream and is presented to a dynamic air classifier which allows fine material to pass and rejects coarser particles for further size reduction in the mill. The mill is "air swept" and hot gases can be introduced to enable the simultaneous drying and grinding of material. Moisture contents of up to 6% can be handled when hot gases are employed. The main wear components are the grinding rolls and table that are supplied in alloy steel. Replacement of these components is expensive but refurbishment using weld overlay techniques have been applied to these components in recent times with some success.

High Compression Roller Mills – Material is force fed into the gap between two counter-rotating rolls that compress and break the particles under a high hydraulic pressure. The rolls are designed such that one roll is fixed and the other is floating by means of hydraulic pressure. As the pressure increases the amount of fines generated increases.

There are similarities to the traditional roll crusher technology but much higher forces mean that the size reduction ratio through the High Compression Roller Mill is far greater.

The High Compression Roller Mill can handle feed material containing a few percent moisture but this needs to be removed prior to any downstream screening and/or air classification process. Dis-agglomeration of the product discharged by the Roller Mill is often also necessary and this is most often achieved using a slow speed impact mill with wear protection.

Factors effecting fineness include feed rate, specific press force and the general flow characteristics of the material.

An area where the High Compression Roller Mill is also used is in the pre-grinding of material prior to a ball milling process. Energy savings of up to 50% can be achieved with this arrangement.

Fluidised Bed Jet Mills – A number of nozzles are arranged concentrically around a cylindrical grinding chamber and converge to a central point. Compressed air is injected into the vessel via the nozzles which entrains the material to be ground and accelerates the particles towards the central point where inter-particle collisions occur. Size reduction of the particles occurs as a result of these inter-particle collisions in the fluidised bed that means there is very little wear in the grinding chamber and therefore little/no contamination to contend with. This makes the Jet Mill ideally suited to tough high purity materials such as zirconium oxide.

The product within the fluidised bed is carried out of the grinding chamber up to a dynamic air classifier that sorts the material by particle size. Fine product is carried out of the Jet Mill for collection in the downstream filter whilst coarse particles are returned to the grinding chamber for further size reduction.

The disadvantage of the Jet Mill is high energy costs (due to the compressed air consumption) which means that this technology is mainly used for the production of high value ultra fine materials at d_{97} 20 micron and below.

Impact Air Classifier Mills – An air classifier mill combines a high-speed impact mill (typically 120 m/s tip speed) with a dynamic air classifier that sorts the particles by particle size/density.

A range of wear protection options are available including hardened steels and technical ceramics but accelerated wear rates and associated high maintenance costs often preclude the use high speed impact mills or impact air classifier mills on abrasive materials such as glass.

Mill Type	Fineness Range (d_{97})	Capital and Installation Cost	Specific Energy Consumption	Wear Costs
Ball Mill	250 – 10 μm	High	Medium/High	Low
Table-Roller Mill	250 – 30 μm	Medium/High	Medium	Medium
High Compression Roller Mill	250 – 45 μm	Medium/High	Low	Medium
Fluidised Bed Jet Mill	125 – 5 μm	Medium	High	Low
Impact Air Classifier Mill	250 – 20 μm	Low	Low/Medium	High

Equipment Vendors:

Ball Mills	Hosokawa Micron Ltd
	British Rema Ltd
	Metso Minerals
	Polysius
Table-Roller Mills	Hosokawa Micron Ltd
	Polysuis
	Metso Minerals
High Compression Roller Mills	Hosokawa Micron Ltd
	Polysius
	Sahut Conreur
Fluidised Bed Jet Mills	Hosokawa Micron Ltd
	Netzsch Condux
	British Rema Ltd

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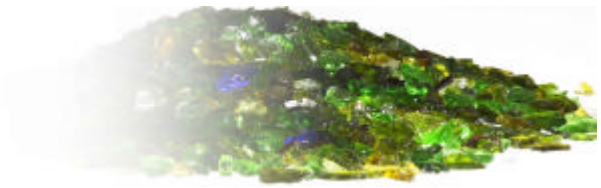

Screening & Air Classification of Glass

Key Issues:

Screening and Air Classification can be utilised in the processing of glass for 2 main purposes:

1. Removal of contamination
2. Control of particle size

Screening is often employed in the crushing stage of the process to remove contamination. The throughput requirement is normally high and moisture is often a restricting factor on separation efficiency. Air classification can also be employed in this area where a significant difference in the relative density and/or size of the glass and contamination can be used as the basis for separation.

Precise control of particle size becomes critical on the more sophisticated higher value applications where powders and/or grits are required in specific particle size ranges. In this area, where maximum yield of product in the required size range is demanded, the extraction efficiency of the separating device is important and considered selection of equipment is essential.

Introduction

When reprocessing glass for any particular market, there are likely to be specific size requirements for the finished glass particles. Important considerations when selecting a screening and air classification technology include:

- Size of particles to be processed
- Throughput
- Whether multiple product gradings are required
- Precision of separation required, i.e. can end-user tolerate oversize/undersize in product

Screening

For contamination removal coarse separations can be achieved using either a **trommel** or **vibratory screen.**

How the Technology Works

Trommel screens - are rotating cylinders with perforations in the exterior chamber wall, or mesh screens through which glass particles can pass depending on the aperture size. All other glass and other contaminants pass through the trommel and out of the other end. The large glass particles can be re-circulated into the processing chamber whilst contaminants are rejected from the system.

Trommel screens can be sized to fit almost any size glass processing operation, and can also be configured to most conveying systems. Warm air can be passed through the chamber to help dry the glass during this stage of processing.

Primary processing can also be achieved by the inclusion of a **Vibratory screen** which is normally operated in conjunction with a crusher. Again, glass particles pass through

the mesh opening whilst larger glass particles and contamination pass over the mesh and out of the machine for either recirculation to the crusher or rejection from the system as appropriate.

For fine separations to produce finished grades of glass grits and powders vibratory screens or gyratory screens are generally employed.

In this area a clear distinction needs to be made between “sizing” screens which are normally utilised where high throughputs are required and “precision” screens where separation efficiency is the main objective and throughputs are generally lower. Sizing screens are often set at an angle to the horizontal whilst precision screens are normally horizontal.

Precision screens are used for finer separations – at low throughputs cuts even down to 75 micron range are possible. In this area effective mesh cleaning is essential to prevent blinding and bouncing ball or ultrasonic mesh cleaning are the devices most commonly employed.

For fine separations moisture needs to be negligible or mesh blinding will quickly occur. To facilitate this some screens are provided with a hot gas purge.

Where several grades are required from a single material a multi-deck machine can be employed. Screens can be provided with up to 5 decks enabling 6 different products to be produced simultaneously.

Air Classification

Where fine separations are required air classification represents an alternative to screening.

Air classifiers are typically used for separations below 250 micron – for coarser separations screening is normally preferred as the more cost effective solution. Air classifiers can, however, be used to produce much finer products than screening with products at minus 10 micron and below being possible in some cases.

The air classifier utilises an airflow to separate products of different size/density. The simplest type, a “unit air classifier” is a self contained unit which generates its own airflow using an internal fan. Feed is introduced from the top by gravity and fine and coarse fractions are discharged from the bottom. The “cut point” (separation size) is controlled by adjustment of airflow, rotor/fan speed and the rising velocity within the vessel.

Other classifiers rely on an external airflow which is normally generated by a fan. These classifiers use a free or forced vortex generated by static vanes or a dynamic classifier wheel which impart centrifugal forces on the particles opposing the centripetal force from the fan. The balance between the 2 forces gives the cut point i.e. which size particles are rejected and which are allowed to pass.

Where moisture is present in the feed material the airstream for classification can be heated enabling simultaneous drying and classification of the product.

When granular products are required with negligible fines a classification stage in the process is sometimes included prior to screening. The removal of fines at this point assists with the screening process and ensures the production clean (dust free) granular products.

Wear can be an issue when using air classification to process glass. Classifier designs are available with wear protection in the areas most susceptible to abrasion. Hard metals, aluminium oxide and polyurethane are most commonly utilised for the purpose of wear protection.

Glass Screening Technologies available in the UK include:-

Locker Process Solutions	General Kinematics Corp
Mogensen	Eriez Magnetics Europe Ltd
Binder and Co. AG	Russell Finex
Vibralfo	Sweco
Skako Comesa	Hosokawa Micron Ltd (Allgaier Werke)

Suppliers of Air Classification Equipment available in the UK include:-

Hosokawa Micron Ltd
British Rema Manufacturing
Bradley Pulveriser Co.
Metso Minerals

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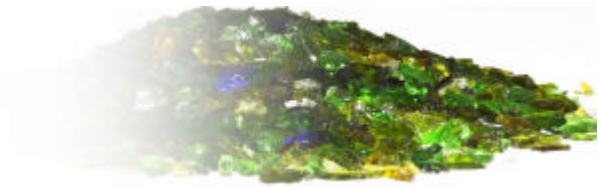

Ferrous Metal Contaminant Removal

Key Issues

Ferrous metal is one of the most common contaminants found in glass waste streams due to its tough and versatile nature, and can arise through a variety of sources such as caps, lids and other fixings.

Ferrous metals have the tendency to cause problems within glass furnaces by causing deposits and chemical reactions. It can also prove problematic within the glass production process by clogging and jamming injection ports.

Other end markets for glass cullet have similar intolerances for ferrous metals due to chemical incompatibility and potential for oxidation.

Also, where contaminants are visibly present in the end product it can contribute to the product being perceived as of low quality.

Introduction

By definition ferrous metals contain iron and are therefore to some extent magnetic, and can be removed simply by integrating magnetic separation technologies into the processing chain.

Magnetic separation equipment is standard to all types of recycling applications and can therefore easily be adapted to suit glass recycling processes.

Several different types of magnetic separators are available on the market. Each can be configured to work with the efficiency of the equipment in place.

Critical issues in selecting the appropriate magnetic separator include:

- Feed rate
- Size of metal to be removed
- Strength of magnetic field
- Thickness of materials stream

Each of these parameters can be adjusted to maximise the efficiency of the system.

Technologies:

Overhead / cross belt magnets - The magnetic field is mounted above the stream of cullet moving along a belt. The overhead magnetic field has a belt moving across its surface at approximately a 90 degree angle to the materials flow. The magnet detects and pulls the ferrous metal from the cullet stream. The metal sticks to a moving belt until it is no longer above the cullet stream, at which point it clears the magnetic field and is discharged. A similar configuration can be achieved with a magnet installed at the end of a conveyor.

Magnetic Head Pulleys - Often situated at the end of a conveyor, a magnetic head pulley is installed beneath the belt and holds the ferrous metal to the belt surface. This allows the glass cullet to be discharged off the belt as normal and onto the next

processing phase. The ferrous material will continue to be held by the belt until it passes a divider and is released from the magnetic field.

Magnetic Drums - Magnetic drums can be installed at several points along the cullet sorting and processing line. The most frequent location is inside feeder chutes, between chutes and conveyors. Similar to a head pulley the material passes over a magnetic drum which generates a magnetic pull which holds ferrous metals to the drum for an extended period whilst allowing non-magnetic material to pass freely through the system. The ferrous material is held to the drum until it passes a divider where it is discharged.

As discussed previously there are many factors which will influence the selection of magnetic technology. Many magnetic systems are custom made to suit that particular application. Also, many equipment vendors now have test facilities where potential customers can take sample feed stocks so that the best solution can be found to suit a particular feedstock.

Magnetic Separation Equipment Available in the UK includes:-

Eriez Magnetics Europe Ltd
MSS Inc
Master Magnets Ltd
Metal Detection Ltd
Peak Separation Equipment Ltd
Magnapower Equipment Ltd

Contact:

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Non-Ferrous Metal Contaminant Removal

Key Issues

Similar to ferrous metals, non-ferrous metals such as brass, aluminium, lead, stainless steel and chrome which are often present through speciality labels and bottle neck wraps can also prove problematic within glass furnaces by causing deposits and chemical reactions.

Their presence can also often damage glass production equipment by blocking injection ports and other sensitive fixings. The inclusion of lead can be a particular concern if left to melt and sink to the bottom of the furnace where it can build up over time and chemically erode the furnace lining, potentially leading to a complete melt through of the furnace wall.

Introduction

Non-ferrous materials are by definition non-magnetic, and must therefore be removed using technologies differing from those used for ferrous separation.

There are two technologies available for the removal of non-ferrous metals; however the most common system is the 'eddy-current' system. Detection and removal systems are also available.

The key criteria for selecting the appropriate system are:

- Particle size
- Particle shape
- Particle conductivity

How the Technology Works:

Eddy Current Systems - work by spinning a magnetic rotor with alternating polarity at high speed. As the non-ferrous metals pass over the drum the alternating magnetic field creates an 'eddy current' in the non-ferrous metals. The force created by the eddy current ejects the particle away from the product stream to a separate collection point.

The eddy current can react with varying strength depending on the metals` specific mass and resistivity.

With many factors affecting the efficiency of these systems care must be taken to select the appropriate technology for the material to be segregated.

In most cases larger particles should be sieved out prior to the eddy current stage in order to prevent larger non-ferrous metallic particles which can often be too heavy for the eddy current to repel and therefore ending up in the final product.

Detection Systems – work by using high sensory detectors to identify the presence of non-ferrous metals. A computer then tracks the position of the contaminant until it can be physically ejected from the material stream, often done using precisely pulsed air jet blasts.

A small percentage of glass can often be lost with the contaminant removed with this system; however this can be minimised by monitoring feedstock and adjusting system accordingly. This loss is considered negligible when compared to the risk of having a load rejected by an end user because contaminants are present.

These systems can be used to detect and remove both ferrous and non-ferrous metals.

Eddy current technology is widely established within the waste management industry and is well suited to identify and segregate non-ferrous metals from a recycled glass feedstock.

Non-Ferrous Metal Contaminant Technology available in the UK includes:

Eriez Magnetics Europe Ltd
MSS Inc
Master Magnets Ltd
Metal Detection Ltd
Peak Separation Equipment Ltd
Magnapower Equipment Ltd

Contacts:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References

Walker Magnetics, Eddy Current Separation Equipment, www.walkermagnet.com
Global Magnetics, www.globalmagnetics.com

Paper & Plastic Contaminant Removal

Key Issues:

Conventional recycling of recycled glass back into the glass manufacturing industry requires only basic screening of organic contaminants such as large pieces of paper and plastic labels and such, because trace organics will simply volatize away at typical glass furnace temperatures. However new alternative other markets such as decorative applications or granular products for blast cleaning and filtration media are more sensitive to the presence of even trace amounts of these contaminants, therefore it is necessary to incorporate additional contaminant removal systems into the process.

Introduction

The most common methods of removing these paper and plastic contaminants are by utilising screening systems.

Once the feedstock is passed through an initial breaker the plastic, paper labels, cardboard, corks and other materials tend to pass through in larger particle sizes than the glass partially due to them having a lower specific gravity. Then by incorporating simple screening methods the glass cullet can pass though the mesh whilst allowing a high percentage of this contamination debris pass over the screen to be discarded.

In addition to mechanical screening, air densification systems can also be applied to remove these types of contaminants. Most often this technology is applied with an air induction system to vacuum dusts and other lightweight particles from the top of the screening unit.

When designing a method of removing paper and plastic contamination, consideration should be given to the desired end market specifications in order to identify the most efficient systems for any type of contamination removal.

Contact:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References:

Clean Washington Centre, Best Practices in Glass Recycling, October 1997

Automated Technologies for Colour Sorting Glass

Key Issues:

Colour sorting has historically been a prerequisite of supplying recycled glass into the container manufacturing industry. This has traditionally been achieved by promoting colour segregation at source or by manually sorting it which can be labour intensive.

Whilst many civic amenity and bring programs promote colour segregation, expansion of the current infrastructure principally through an increase in kerbside and commercial collections will inevitably generate substantial volumes of mixed colour cullet. Although some new alternative markets are emerging which are not colour specific, generally the higher value markets still require the glass to be colour sorted.

Due to the costs associated with manual sorting, re-processors have welcomed the introduction of automated technologies that can provide increasingly efficient sortation of mixed-colour cullet into its component colours.

Early technologies for automated colour sorting could only process glass at low throughputs and would frequently experience operating problems or maintenance shutdowns due to the abrasive and dusty nature of recycled glass.

Introduction

Over the past decade, automated colour sorting technologies have improved in performance, cost, reliability, and throughput. They still however continue to be principally utilised by large cullet re-processing facilities.

Glass bottle manufacturers typically distinguish three main colours for supply of recycled glass; namely flint, amber and green.

Glass collection schemes vary in the degree to which consumers are requested to sort by colour. Bottle banks usually require consumers to colour sort at deposit sites, whilst kerbside schemes often collect commingled glass some schemes will colour segregate at the kerbside to retain the highest possible value for the glass. Commercial collections often generate mixed coloured glass as often participants claim to not have sufficient room for three separate bins.

This variation in supply will influence the degree of sorting required by re-processors. If glass containers are not colour sorted by the consumer, then recyclers have two principal options: sort the glass at the point of collection, or colour-sort the glass at their facility.

Many facilities use manual colour sorting; however this is only effective when glass particles are large enough to recognize and handle. Manual sorting is often unable to handle any 2-inch minus broken glass, which can mean the loss of 40% or more of the glass from commingled collection programs as mixed-colour residual.

The degree of colour sorting should depend on the target end markets and associated specifications. Automated colour sortation technologies can either be used to improve the quality of pre-sorted glass cullet, or it can be used to achieve a three-way colour sort.

How the Technology Works:

Automated colour-sorting uses optical technology that has evolved from early systems designed to remove ceramic contaminants. The system configuration is similar to automated ceramic removal equipment, although colour-sorting technology uses a different optical method. Before the automated colour sortation process begins, the equipment must be programmed to recognise the colour of material to be removed. Automated systems can generally be instructed to remove any one or a combination of glass colours.

Typically ceramic removal is done prior to colour sorting to reduce problems with colour sorting associated with these contaminants.

The cullet is fed into the colour-sorting unit by a vibrating conveyer belt, which keeps the glass in a thin layer. As it enters the unit, the cullet passes over a plate embedded with fibre optic cables. A fast pulsing light source is projected through the glass stream to the fibre optics cables, which detect the amount of light transmitted through each particle, determining its colour. Following the programmed colour-removal scheme, the system detects the position of the selected particle and directs one of a series of "air knives" to remove it with a jet of air. Equipment of this type can process up to 10 tonnes of cullet per hour; however this will vary depending on the degree of contamination i.e. the greater the degree of contamination the slower the throughput!

There should be some degree of contaminant removal if possible before the colour sort process to reduce the degree to which paper and other contaminants affect the amount of light being transmitted through each piece if glass and hence reducing the efficiency of the system.

It should be noted that fine-sizing equipment produces a cullet powder that is too small to colour sort (typically 1.5 mm or finer). However, many fine sizing applications do not require colour separation.

Contacts:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References:

Bickman, Josh, Magnetic Separation Systems (MSS), Inc., Nashville, TN

Matheson, Greg, BFI, 1533 120th Avenue NE, Bellevue, WA, telephone conversation, 10/11/96.

Strom, Hank, BFI, 1533 120th Avenue NE, Bellevue, WA, telephone conversation, 10/10/96.

Zimmerman, Don, Recycle America, 7901 First Avenue South, Seattle, WA, telephone conversation, 10/14/96.

Ceramic Contaminant Removal

Key Issues:

Most contaminants found in the post consumer glass waste stream are such that their properties are adequately different from the glass to be separated by mechanical methods. However this is not the case with ceramics, have similar physical properties to glass.

Ceramics do not exhibit magnetic properties, or have different specific gravity to glass, and therefore identifying and removing this material from the glass waste stream has long been a challenge for recyclers and processors of glass.

This similarity in properties means that with some markets ceramics content is not problematic; however when the glass is used in glass manufacturing the presence of ceramics can potentially cause inclusions which cause weaknesses and are unsightly in the finished product.

Introduction

There are three methods for removing ceramic contamination from recycled glass:

Source reduction – The most efficient means of ceramics removal is by reduction at source. This can be achieved through increased public awareness and education programmes.

Manual removal – By using 50mm screens larger items in waste stream can be retained examined by trained personnel who can remove any unwanted ceramics.

Automated ceramic removal – This involves using fibre optic cables. The fibre optic emits pulses of light that pick out opaque material. Then similar to colour separation technologies a pneumatic blast ejects the unwanted particle from the stream. These technologies typically require the particle to be between 15 and 40mm to optimise efficiency and can operate at up to 20T/hr.

Where automated technologies are utilised there should be some degree of contaminant removal prior to this stage in order to reduce other opaque contaminants interfering with the ceramics removal system.

An alternative method to removal is to size reduction. Ceramic particles can be reduced to a particle size which may be may be suitable for the glass manufacturing sector, where they are small enough to melt during the furnace cycle. However care must be taken to ensure the size of ceramic particle is suitable for the desired end market. For instance ceramic particle larger than 0.25mm would block a spinner when used in fibreglass production and indeed in glass manufacturing would cause a flaw in the end product and therefore 0.25mm is the starting point and down.

Ceramic Removal Equipment Vendors include:

Binder
MSS
S+S

Contact:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References:

Clean Washington Centre, Best Practices in Glass Recycling, October 1997

Conveyor Technologies

Key Issues

Conveyors are one of those given system components that often get little attention in the overall system design. However, conveyors are a critical part of maintaining system throughput capacity and must operate continuously for long periods of time without failing. Glass containers can create an especially rough operating environment for conveyors with sharp broken bottle sections, highly abrasive grit and dust, and sticky beverage residues.

Introduction

Glass is highly abrasive, contains sharp edges, and tends to produce fine sized pieces and a gritty dust. As a result, glass can cause excessive wear on both the processing equipment, as well as the conveyor belts that are used to move the glass to the various stages of processing.

Equipment made specifically for processing glass cullet not only has enclosed chambers for crushing the material, but also have protected other parts of the equipment. Along the conveying system, equipment should have sealed bearings, enclosed gear boxes and other moving parts to protect them from cullet dust and grit.

Equipment handling glass in the primary processing stages must also be protected from contaminants including moisture.

Equipment should have the flexibility to operate at variable speeds. This is accomplished either through a variable speed driver, or through gear shifts from the driver to the pulleys.

Things to consider when designing a conveyor system are:

- **Cleats** – If the glass is wet a belt without cleats may be preferred to allow for a scrapper bar to clear the belt. It is also easier to enclose a belt without cleats. However where a steep incline is required cleats can aid flow.
- **Bearings** – Due to its highly abrasive nature glass can build up on pulley bearings and other sensitive parts of the conveyors over time and as such should be protected. This can be done with regular cleaning or by sealing the bearings.
- **Drives** – When selecting a drive system, consideration must be given to the variability of end markets. If the system will be feeding into several end markets, then speed variability may aid final product processing.
- **Surface** – The durability of the belt surface is an important cost consideration. Rubber belts are common but wear rapidly. Steel vibratory conveyors are increasingly being used with recycled glass as this reduces the wear rate associated with traditional rubber belts. However they can be susceptible to wear from glass dust. Vibratory conveyors are often used to produce a uniform layer of feedstock.

When designing a system the variability of recycled glass must be considered as moisture and organic residue can prove particularly problematic causing build up on the belts; however if the feedstock is particularly dry then glass dusts can cause excessive wear on bearings and other movable parts.

Glass Conveyor Technologies available in the UK include:-

General Kinematics Corp
Locker Process Solutions
Mogenson
Binder and Co. AG
Vibralfo
Skako Comesa
Eriez Magnetics Europe Ltd.

Contact:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References:

Clean Washington Centre, Best Practices in Glass Recycling, October 1997

Moisture Considerations & Drying Technologies

Key Issues:

The presence of moisture can significantly affect the handling and processing of recycled glass. It typically arises from two sources, namely rainwater / dew or from residues remaining from the cullet's original use. Glass grain can potentially retain up to 15% by weight of moisture.

Processing glass whilst it is either too wet or dry can prove problematic. If moisture is available on the particle then the surface tension is increased, contributing to the particles sticking together. This can increase wear and tear of equipment parts and diminishes the efficiency of sieving systems by clogging of the apertures, reducing the screening efficiency.

This is due to increased surface tension between fine particles caused by the presence of moisture. Drying will allow particles to flow more freely and provide for efficient screening. Drying also helps to eliminate surface residues and aid in the removal of trace paper and other contaminants

Glass cullet which is too dry can also cause problems as it can prove difficult to handle as there is a reduced surface tension. The ease of flow can make stockpiling difficult.

A lack of moisture can also make dust a nuisance particularly if it is airborne. This can be overcome by introducing misting technologies or containment systems.

Introduction

Typically glass below 4mm will require some degree of drying before the screening stage. This is particularly important when producing a tight gradation of glass grain.

The most common dryer is a drum dryer, which are usually placed before the glass is pulverized. The material flows from one end of the drum to the other as it rotates and is typically heated by air from a gas burner being blown through the drum.

In some systems drying can be combined with screening and is often done using a trommel screen with a heat source situated at the bottom of the trommel drying the glass as it flows downward.

Heat sources can also be used in conjunction with vibratory screens. Vibratory screens are often used for the efficient screening of glass grain into specific grades. The motion reduces the risk of blockages. Heat sources with fans can be positioned so that the heat is projected up through the screen although this can generate airborne dust within the system.

Heated screens are not as effective with very wet glass and as such the feed stock should be dry before the screening stage where possible.

Fluidized bed dryers are also available for drying cullet.

Contacts:

Remade Scotland
Caledonian Shanks Centre for Waste Management
Drummond House (3rd Floor)
1 Hill Street
Glasgow, G3 6RN
Tel: 0141 582 0450
Contact: Hugh McCoach
E-mail: h.mccoach@gcal.ac.uk

References:

Clean Washington Centre, Best Practices in Glass Recycling Report, October 1997

8. Crushing & Colour Sortation Equipment Specification Sheets

This section takes a closer look at particular crushing and colour sortation equipment for glass. For further technical information on any pieces of equipment please contact the vendors direct.

The selection of companies in this section is not a definitive list and we are aware that other glass equipment vendors may exist. However, through time we aim to develop as comprehensive a list as possible and welcome your input. Therefore, if you are aware of a company that you feel should be included, or have any comments please feel free to contact us.

Crushing Equipment

American Pulverizer Company

Product Range

The American Pulverizer Company originally started selling coal crushers; however they now offer a complete range of slow speed, high torque, shear-type shredders, high speed ring and hammermills, auger shredders, single and double roll crushers as well as cage mills and rotary trommel screens. They also offer a wide range of conveyors through their subsidiary organisation "Hustler Conveyor Company".

Contact Details

American Pulverizer Company
5540 West Park Avenue, St. Louis
USA
MO 63110
Tel: 314 781 6100
Contact: Chris Griesedieck
E-mail: info@ampulverizer.com
Web-site: www.ampulverizer.com

Product Description

They supply a wide variety of crushers to suit many processors` requirements. The number of breakers bars required will vary depending on the type and size of crusher and can range between £35 and £235 each.

The equipment can be manufactured to be either mobile or static and has safety features such as guards and easy access to the interior of the machines.

At present there they have not supplied any units to the UK.

Glass Crushing Equipment Key Parameters

Model	SRLB	Hammermill	Impactor
Throughput (T/hr)	20	40	40
Feedstock	Full Bottles	Full Bottles	Full Bottles
PSD After 1 Pass	19mm minus	9.5mm minus	19mm minus
Footprint (LxWxH)	26 Different sizes available	20 Different sizes available	24 Different sizes available
Crusher Type	Finger Comb Arrangement	Top Fed Hammermill	Horizontal Shaft Impactor
No. of Hammers	Varies depending on type of machine	Varies depending on type of machine	Varies depending on type of machine
Hammer Design Life	Depends on product size	Depends on product size	Depends on product size
Operators Required	1 - 2	1 - 2	1 - 2
Capital Cost	~ £7,550	~ £15,725	~ £11,320
Operating Cost	Varies	Varies	Varies
Delivery Time	6 – 8 Weeks	12 Weeks	14 Weeks
Warranty Duration	1 Year	1 Year	1 Year

Andela

Product Range

Andela produces breaker systems, pulverizer systems, windshield stripper systems, cathode ray tube (CRT) recycling systems. They also supply ancillary equipment such as conveyors, hoppers, screens, magnets, eddy current systems to complement their equipment.

Contact Details

Andela (UK)
c/o CAMEXCEPT Ltd
Lilac Cottage, Mill Lane
Normanton On Trent, Newark
Nottinghamshire, NG 23 6RW
Tel: 01636 821904
Contact: Michael Brabham
E-mail: comexcept@hotmail.com
Web-site: www.andelaproducts.com

Product Description

In recent years Andela have become established as one of the principal glass processing equipment suppliers in the USA and are now supplying their equipment worldwide. Although based in the USA they have now appointed UK representatives (detailed above). At present they do not have any equipment in the UK; however they expect to have a unit operational in the north of England in the coming year.

They supply 3 glass crushing systems with significant size reduction capabilities after one pass producing glass suitable for a range of end markets.

The technologies work using a rotating flail hammer mill crushing method. The number of hammers varies depending on the size of equipment and can cost between £1300 and £3000 per set to replace depending on the model.

Andela are also offering design, build and operate services suitable for Material Recovery Facilities (MRF's) which can separate commingled recyclables (glass, plastic and cans).

Glass Crushing Equipment Key Parameters

Model	GP-07	GP 1	GP 2
Throughput (T/hr)	1 – 3	2 – 10	10 - 20
Feedstock	Full Bottles	Full Bottles	Full Bottles
PSD after 1 pass	9.5mm minus	9.5mm minus	9.5mm minus
Footprint (LxWxH)	1.35 x 1.35 x 2.64m	1.68 x 1.7 x 2.92m	2.16x2.21x3.12m
Crusher Type	Rotating flail hammer mill	Rotating flail hammer mill	Rotating flail hammer mill
No. of Hammers	48	68	56
Hammer Design Life	~600 operating hours	~600 operating hours	~600 operating hours
Operators Required	2	2	2
Capital Cost	£90,000	£110,000	£140,000
Operating Cost	~£1.36 / T	~£0.76 / T	~£0.50 / T
Delivery Time	12 – 16 weeks	12 – 16 weeks	12 – 16 weeks
Warranty Duration	2080 hours	2080 hours	2080 hours

C.S.Bell

Product Range

C.S.Bell supply grinding mills, hammer mills, portable and stationary conveyors.

Contact Details

C.S.Bell
c/o Envirobanks Ltd
Wales
Tel: 01291 630 440
Contact: Mark Chapman
Web-site: www.csbellco.com

Product Description

The 3 units are all mobile however the throughputs are not adjustable on these crushers. C.S.Bell have previously sold HMG-05P and the HMG-16P units to the UK.

The HMG-40 uses wear resistant hammers which are reversible therefore doubling their design life.

Custom designed equipment can be built to meet customer requirements.

Glass Crushing Equipment Key Parameters

Model	HMG-05P	HMG-16P	HMG-40
Throughput (T/hr)	2	4	13+
Feedstock	Full Bottles	Full Bottles	Full Bottles
PSD After 1 Pass	73% @ 19mm minus	86% @19mm minus	67% @ 19mm minus
Footprint (LxWxH)	1.1 x 1.0 x 1.6m	3.8 x 1.2 x 2.4m	97 x 79 x 107cm
Crusher Type	Impact Hammer	Impact Hammer	Hammer Mill
No. of Hammers	2	4	10
Hammer Design Life	Variable	Variable	Variable
Operators Required	1	1	1
Capital Cost	~ £1,160	~ £3,015	~ £3,050
Operating Cost	~ £9.12 Breaker Bars	~ £9.43 Breaker Bars	~ £10.69 Breaker Bars
Delivery Time	30 Days	30 Days	30 Days
Warranty Duration	1 Year	1 Year	1 Year

Donico

Product Range

Donico supply a range of pulverizers, pre-crushers, hoppers, screens, conveyors and dust collection equipment.

Contact Details

Donico
c/o UK Glass Recycling Ltd
Unit 26 Adlington Industrial Estate
Adlington
Cheshire, SK10 4NL
Tel: 0870 758 8848
Contact: Malachy Quinn
E-mail: info@ukglassrecycling.com
Web-site: www.ukglassrecycling.com

Product Description

The Donico R-1000 and R-3000 Micro-Source Pulverizing Systems work using a rotary impact pulverizer which uses a combination of air pressure and centrifugal force to reduce glass to a sand size. The systems are completely enclosed to prevent glass dust becoming airborne during processing.

Each Micro-Source Pulverizing System comes with a spare rotor frame and two extra sets of blades, spare liner pieces and a set of extra D/C filters to help reduce the first year's maintenance costs.

A set of blades for the Micro-Source system cost approximately £190 whereas a set of knives/hooks for the SW-25 cost approximately £1260.

There are as yet no units in the UK; however they expect to have one set up in the near future. Donico are also currently working on their web-site which will go live soon.

Glass Crushing Equipment Key Parameters

Model	R-1000	R-3000	SW-25
Throughput (T/hr)	5 Micro-Source	10 Micro-Source	60-75 Windscreens / Hour
Feedstock	Full Bottles	Full Bottles	Windscreens
PSD After 1 Pass	Aggregate / Sand Size	Aggregate / Sand Size	1.3cm strips of vinyl / glass
Footprint (LxWxH)	7.32 x 3.05 x 3.05m	9.14 x 4.88 x 3.05m	2.44 x 2.44 x 3.05m
Crusher Type	Rotary Impact Pulverizer	Rotary Impact Pulverizer	Low Speed Shredder, High Torque
No. of Hammers	Rotor with 7, 9 or 11 Blades	Rotor with 7, 9 or 11 Blades	Shaft with 20 to 36 Knives / Hooks
Hammer Design Life	3 to 6 Months Reversible	3 to 6 Months Reversible	6 to 9 Months
Operators Required	1	1	1
Capital Cost	~ £78,615	~ £110,060	~ £37,735
Operating Cost	~ £0.63 / T	~ £0.94 / T	~ £0.63 / Windscreen
Delivery Time	4 to 6 Weeks	4 to 6 Weeks	4 to 6 Weeks
Warranty Duration	3 Years / Housings	3 Years / Housings	2 Years / Chamber

Glass Aggregate Systems (GAS)

Product Range

Glass Aggregate Systems supply vibratory flow conveyors, trommel screens, magnets and dust control equipment to compliment their range of crushing units.

Contact Details

Glass Aggregate Systems (GAS)
c/o Technical Engineering Services (UK) Ltd
Carlisle
Tel: 01228 525972
Contact: Howard Graham
E-mail tesukltd@yahoo.co.uk
Web-site: http: www.glassagg.com

Product Description

Formerly known as GAME, Glass Aggregate Systems supply 5 glass crushing systems and also a mobile unit. They have supplied equipment across the USA, South America and Japan; however at present there are none in the UK.

The throughputs can be adjusted on all the crushers excluding the H 100, which is a manually fed machine, whereas all the other units are vibratory flow controlled.

The equipment has safety features such as protective guards and an emergency shut-off system.

There is also technical support available for installation, parts and service.

Glass Crushing Equipment Key Parameters

Model	H 100	H 100VT	H200	GM 2	GM 1
Throughput (T/hr)	300-500lbs / hr	1T / hr	2T/hr	3 – 10T/hr	10 – 20T/hr
Feedstock	Whole Bottles	Whole Bottles	Whole Bottles	Whole Bottles	Whole Bottles
PSD After 1 Pass	13mm minus	13mm minus	13mm minus	13mm minus	13mm minus
Footprint (LxWxH)	0.91 x 1.22 x 1.68m	5.64 x 1.68 x 3.66m	4.88 x 4.27 x 1.68m	12.2 x 8.53 x 3.2m	12.2 x 8.53 x 3.51m
Crusher Type	Shear Drum & Tines	Shear Drum & Tines	Shear Drum & Tines	Shear Drum & Tines	Shear Drum & Tines
No. of Hammers	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Breaker Bars Design Life	2 Years	1 – 2 Years	1 – 2 Years	1 – 2 Years	1 – 2 Years
Operators Required	1	1	1	1	1
Capital Cost	~ £5,975	~ £20,125	~ £28,300	~ £53,460	~ £60,380
Operating Cost	~ £0.79 / T	~ £0.53 / T	~ £0.53 / T	~ £0.35 / T	~ £0.35 / T
Delivery Time	10 – 12 Weeks	10 – 12 Weeks	10 – 12 Weeks	10 – 12 Weeks	10 – 12 Weeks
Warranty Duration	1 Year Wear Parts 6 Months	1 Year Wear Parts 6 Months	1 Year Wear Parts 6 Months	1 Year Wear Parts 6 Months	1 Year Wear Parts 6 Months

IMS Engineering Ltd

Product Range

IMS Engineering Limited manufactures and supply balers, shredders and conveyors for different applications worldwide.

Contact Details

IMS Engineering Ltd
Unit S1B, Tursdale Business Park
Tursdale, Co. Durham
DH6 5PG
Tel: 0191 377 8880
Contact: Neil Johnson
E-mail: ims-eng@talk21.com
Web-site: www.ims-eng.sageweb.co.uk

Product Description

This crusher can be supplied with conveyors, screening systems, magnets, eddy current separators, washers, dryers and dust control equipment.

The crusher teeth for this unit costs £9,650 for a full set of eight. Bearings are outboard, self aligning, and protected by mechanical seals.

This piece of equipment has previously been installed at Pilkington Plc plant.

Glass Crushing Equipment Key Parameters

Model	Lancaster 24x32 Crusher
Throughput (T/hr)	30
Feedstock	Full Bottles
PSD After 1 Pass	95% 19mm minus
Footprint (LxWxH)	1.7 x 1.7 x 0.715m
Crusher Type	Twin Roll Crusher
No. of Hammers	Each Roll Has 4 Segments
Breaker Bars Design Life	3 – 4 Years
Operators Required	1
Capital Cost	£54,500
Operating Cost	~ £1300 / Year
Delivery Time	16 – 18 Weeks
Warranty Duration	1 Year

Krysteline

Product Range

Krysteline have a range of glass processing equipment which they offer by means of a partnership arrangement. They manufacture 5 glass processing systems with ancillary equipment such as conveyors and high temperature dryers.

Contact Details

Krysteline
One Thorne Way, Woolsbridge Industrial Park
Three Legged Cross, Wimborne
Dorset, BH24 6SP
Tel: 08706 000 033
Contact: Steve Wettingsteel
E-mail: enq@krysteline.net
Web-site: www.krysteline.net

Product Description

Krysteline use a patented glass imploder system for processing the glass. The glass can be in the form of containers, or flat glass. The Krysteline glass imploders can process glass to meet a variety of end markets and can be complimented with ancillary equipment such as high temperature dryers, discharge conveyors and bagging lines to refine and compliment the final product.

Krysteline are not looking to sell their equipment, but are looking to rent it and form partnerships with processors and end users. This type of service has the benefit of there being no large capital investment required and they can provide continuous technical and maintenance support. For further information regarding the types of partnerships they offer please contact Krysteline direct.

Krysteline offer a 365 day, 24 hour technical help desk nationwide for support.

Glass Crushing Equipment Key Parameters

Model	GC 10 & 20	GC 4	GPC 15	GPC 30	GPC 60
Throughput (T/hr)	1	4	15	26	44
Feedstock	Full Bottles	Full Bottles	Full Bottles & flat glass	Full Bottles & flat glass	Full Bottles & flat glass
PSD After 1 Pass	20 - 0.075mm (Average 5mm)	20 - 0.075mm (Average 5mm)	20 - 0.01mm (Average 3 - 5mm)	20 - 0.01mm (Average 3 - 5mm)	20 - 0.01mm (Average 3 - 5mm)
Footprint (LxWxH)	0.42 x 0.35 x 1.3m	1.0 x 1.0 x 1.55m	13 x 4m (Footprint)	46 x 6m (Footprint)	80 x 30m (Footprint)
Crusher Type	Glass Imploder	Glass Imploder	Glass Imploder	Glass Imploder	Glass Imploder
No. of Hammers	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Operators Required	1	1	2	3	4
Capital Cost	Not For Sale	Not For Sale	Not For Sale	Not For Sale	Not For Sale
Operating Cost	£3.2 / T	£3.2 / T	Commercially Sensitive		
Delivery Time	14 Days	14 Days	90 Days	90 Days	120 Days
Warranty Duration	1 Year	1 Year	2 Years	2 Years	2 Years

Magco Tollemache Ltd

Product Range

Magco Tollemache Ltd offers a wide range of roll crushers and vertical hammermills. They can also supply heavy duty electromagnetic vibratory feeders, inclined and horizontal feeders, screens and dryers to compliment their crushers.

Contact Details

Magco Tollmache Ltd
County Estate, Sutton-in-Ashfield
Nottinghamshire
NG17 2HW
Tel: 01623 440 990
Contact: Denby Slingsby
E-mail: denby.slingsby@langley-group.co.uk
Web-site: www.magco-tollemache.co.uk

Product Description

Their roll crushing units can be designed and tailor made to suit a variety of customer requirements. The throughputs on all their equipment is adjustable and they can handle feedstocks larger than bottle-size.

The equipment comes with safety features such as safety locks, enclosed sections, tramp metals relief mechanism and inspection doors as standard.

The equipment is automated and therefore requires minimal manpower to operate.

Glass Crushing Equipment Key Parameters

Model	Single Stage Roll Crusher 2020S	Single Stage Roll Crusher Large Units	2 Stage Roll Crushers 2030D	Vertical Hammermill 25	Vertical Hammermill 42
Throughput (T/hr)	5 – 60	Variable	5 – 80	5 – 25	20 – 100
Feedstock	Full Bottles	Full Bottles	Full Bottles	Full Bottles	Full Bottles
PSD After 1 Pass	6 – 60mm Variable	Variable	6 – 60mm Variable	2mm minus	2mm minus
Footprint (LxWxH)	1.3 x 1.6 x 0.8m	Variable	2.1 x 1.8 x 1.3m	1.8 x 0.7 x 1.4m	2.6 x 1.8 x 6.4m
Crusher Type	Roll Crusher	Roll Crusher	Roll Crusher	Vertical Shaft Impactor	Vertical Shaft Impactor
No. of Hammers	2 Rolls (Various Teeth Designs)	Variable	4 Rolls	20	24
Breaker Bars Design Life	Variable	Variable	Variable	Variable	Variable
Operators Required	1	Variable	1	1	1
Capital Cost	£25,000 - £35,000	Variable	Variable	Variable	Variable
Operating Cost	Minimal	Minimal	Minimal	Variable	Variable
Delivery Time	10 – 14 Weeks	Variable	10 – 14 Weeks	12 – 16 Weeks	12 – 16 Weeks
Warranty Duration	1 Year	1 Year	1 Year	6 – 12 Months	6 – 12 Months

Colour Sortation & Contaminant Removal Equipment

Binder

Product Range

Binder manufactures a range of glass colour sort equipment, ceramics removal, metal removal, screening, drying and washing equipment.

Contact Details

Binder
Grazer StraBe 19-25
A - 8200 Gleisdorf
Austria
Tel: +43 3112 8000
Contact: Christian Makari
Web-site: www.binder-co.at
E-mail: christian.makari@inode.at

Product Description

Both the Clarity 1000 and 14000 can eject 2 fractions from the throughput whereas the Compact-1 removes only 1 fraction. The camera technology used can differentiate between 16 Mio. colours.

Binder recommends that the equipment is serviced once a year to maintain efficiency.

Colour Sortation Equipment Key Parameters

Model	Clarity 1000	Clarity 1400	Compact-1
Throughput (T/hr)	10	14	4
Feedstock	8 – 60mm	8 – 60mm	5 – 60mm
Processed Glass (% of contaminant removed after 1 pass)	Depends on composition capacity and quality of input		
Footprint (LxWxH)	1.2 x 1.5 x 1.0m	1.2 x 1.9 x 1.0m	1.2 x 1.9 x 1.0m
Technology	Camera	Camera	Camera
No. of Air Knives	80	112	40
Operators Required	1	1	1
Capital Cost	~ £109,285	~ £137,143	~ £50,000
Delivery Time	4 Months	4 Months	4 Months
Warranty Duration	1 Year	1 Year	1 Year

S+S Metallsuchgeräte und Recyclingtechnik GmbH

S+S Inspection Ltd (UK subsidiary of S+S GmbH)

Product Range
S+S design and manufacture a range of class leading glass sorting equipment for the following applications:

Colour Sorting – Two or Three colours in one pass
CSP - Ceramics, Stone and Porcelain Removal
X-Ray - PYRO-Ceramic / Heat resistant glass removal
Metal Detection - Metal Separation

Contact Details UK
S+S Inspection Ltd
25 Barnes Wallis Road
Segensworth East
FAREHAM
Hampshire
PO15 5TT
Tel: +44(0)1489 889 824
Contact: Christopher Perkins
Web-site: www.splussinspection.co.uk
E-mail: info@splussinspect.co.uk

Contact Details GmbH
S+S Metallsuchgeräte und Recyclingtechnik GmbH
Regener Straße 130
94513
Schoenberg
GERMANY

Tel: +49(0)8554-3080
Contact: Peter Mayer
Web-site: www.ss-metal-detection.com
E-mail: info@ss-gmbh.de

Product Description
Combining camera, laser and X-ray technology with our thoroughly tested air reject facilities provides S+S with the most comprehensive array of equipment for the discerning glass recycler.
Key Parameters

Model	**Spektrum** Colour sorting	**LAG** CSP Removal	**MAG** Metal Removal	**Varisort-X** Pyro Ceramic removal
Av. Throughput (T/hr)	2.5 - 10	5 – 25	5 - 30	Up to 10
Feedstock	10mm – 60mm 5mm available	2mm – 60mm	2mm – 60mm	5 – 60mm
Processed Glass (% of contaminant removed after 1pass)	Dependant on model and specification and composition and quality of input glass.			
Footprint	Various working widths available	Various working widths available	Various working widths available	Various working widths available
Technology	Camera	Laser	RF Coil	X-Ray
No. of Air Separators	Variable by specification	Variable by specification	Variable by specification	Variable by specification
Operators Required	**1**	**1**	**1**	**1**
Capital Cost	Variable by specification	Variable by specification	Variable by specification	Variable by specification
Delivery Time	3 - 4 Months	3 - 4 Months	3 - 4 Months	3 - 4 Months
Warranty Duration	1 Year	1 Year	1 Year	1 Year

MSS

Product Range

MSS produce colour sort, ceramic removal, metal removal equipment and vibratory systems.

Contact Details

MSS
c/o PPS Recovery Systems Ltd
9 Metro Centre
Welbeck Way, Woodston
Peterborough
PE2 7WH
Tel: 01733 390 029
Contact: Ian Smith
E-mail: ian.smith@pps-ltd.com
Web-site: www.pps-ltd.com

Product Description

The MSS glass ColourSort™ can process up to 20 tonnes per hour depending on the quality of the feedstock.

The glass cullet is fed through the unit via a stainless steel vibratory system. The sensing array identifies the material by its colour or opacity. The system activates and controls a precision air jet to eject the required material (glass or opaques).

A single colour stream will be removed with each pass; however the machine can be operated in a "split mode" where each half of the machine can remove a single colour from the input stream.

They have supplied several units to the UK.

Colour Sortation Equipment Key Parameters

Model	MSS Glass ColourSort™
Throughput (T/hr)	5
Feedstock	15 – 40mm (Optimum - although can sort pieces outside this range)
Processed Glass (% of contaminant removed after 1 pass)	>95%
Footprint (LxWxH)	1.9 x 1.7 x 1.8m
Technology	Sensor Technology (high speed optical detectors)
No. of Air Knives	96
Operators Required	1
Capital Cost	Circa £85 – 90,000 (ex-works)
Delivery Time	12 – 16 weeks
Warranty Duration	1 Year

9. Appendix 1: Mesh Sizes

US. Standard Mesh	Sieve Opening
No. 3.5	5.66mm
No. 4	4.75mm
No. 5	4.00mm
No. 6	3.35mm
No. 7	2.80mm
No. 8	2.36mm
No. 10	2.00mm
No. 12	1.70mm
No. 14	1.40mm
No. 16	1.18mm
No. 18	1.00mm
No. 20	0.850mm
No. 25	0.710mm
No. 30	0.600mm
No. 35	0.500mm
No. 40	0.425mm
No. 45	0.355mm
No. 50	0.300mm
No. 60	0.250mm
No. 70	0.212mm
No. 80	0.180mm
No. 100	0.150mm
No. 120	0.125mm
No. 140	0.106mm
No. 170	0.090mm
No. 200	0.075mm
No. 230	0.063mm
No. 270	0.053mm
No. 325	0.045mm
No. 400	0.038mm
No. 450	0.032mm
No. 500	0.025mm
No. 635	0.020mm
Sieve Pan	5/8" Deep
Sieve Pan	1" Deep
Sieve Pan	2" Deep
Sieve Cover	

Table 14 Mesh sizes

Mesh Count Per Inch	Diameter of Wire		Width Of Opening		Micron Size	Open Area
	Inches	mm	Inches	mm		
2	0.063	1.6	0.437	11.1	11100	76.4%
3	0.054	1.37	0.279	7.09	7090	70.1%
4	0.047	1.19	0.203	5.16	5160	65.9%
5	0.041	1.04	0.159	4.04	4040	63.2%
6	0.035	0.89	0.132	3.35	3350	62.7%
8	0.028	0.71	0.097	2.46	2460	60.2%
10	0.025	0.64	0.075	1.91	1910	56.3%
12	0.023	0.584	0.06	1.52	1520	51.8%
14	0.02	0.508	0.051	1.3	1300	51.0%
16	0.018	0.457	0.0445	1.13	1130	50.7%
18	0.017	0.432	0.0386	0.98	980	48.3%
20	0.016	0.406	0.034	0.86	860	46.2%
24	0.014	0.356	0.0277	0.7	700	44.2%
30	0.013	0.33	0.0203	0.52	520	37.1%
35	0.011	0.279	0.0176	0.45	450	36.9%
40	0.01	0.254	0.015	0.38	380	36%
50	0.009	0.229	0.011	0.28	280	30.3%
60	0.0075	0.191	0.0092	0.23	230	30.5%
70	0.0065	0.165	0.0078	0.2	200	29.8%
80	0.0055	0.14	0.007	0.18	180	31.4%
90	0.005	0.127	0.0061	0.16	160	30.1%
100	0.0045	0.114	0.0055	0.13	140	30.3%
110	0.004	0.1016	0.0051	0.1295	129.5	31.4%

120	0.0037	0.094	0.0046	0.117	117	30.5%
130	0.0034	0.086	0.0043	0.109	109	31.1%
140	0.0029	0.074	0.0042	0.107	107	34.9%
150	0.0026	0.066	0.0041	0.104	104	37.4%
160	0.0025	0.064	0.0038	0.0965	96.5	37.6%
170	0.0024	0.061	0.0035	0.0889	88.9	35.1%
180	0.0023	0.0584	0.0033	0.0838	83.8	34.7%
200	0.0021	0.0534	0.0029	0.0737	73.7	33.6%
250	0.0016	0.0406	0.0024	0.061	61	36%
270	0.0016	0.0406	0.0021	0.0533	53.3	32.2%
325	0.0014	0.0356	0.0017	0.0432	43.2	30.5%
400	0.001	0.0254	0.0015	0.037	37	36%
500	0.001	0.0254	0.001	0.0254	25.4	25%
635	0.0008	0.0203	0.0008	0.0203	20.3	25%

10. Appendix 2: Glass Processing Equipment Vendors

Company	Equipment	Contact Details
Alan Ross Machinery Corp	Screening, Drying, Metal Separators, Dust Collectors	3240 Commercial Avenue, Northbrook, Chicago, IL 60062 USA Tel: 001 847 480 8900 Contact: Alan Ross E-mail: director@rossmach.com Web-site: www.rossmach.com
American Pulverizer Company	Crushing Equipment	5540 West Park Avenue, St. Louis, MO 63110, USA Tel: 001 314 781 6100 Contact: Chris Griesedieck E-mail: info@ampulverizer.com Web-site: www.ampulverizer.com
Andela	Crushing & Screening Equipment	CAMEXCEPT Ltd, Lilac Cottage, Mill Lane, Normanton On Trent, Newark, Nottinghamshire, NG23 6RW Tel: 01636 821904 Contact: Michael Brabham E-mail: comexcept@hotmail.com Web-site: www.recycle.net/andela
Binder	Crushing, Drying, Washing, Colour Sortation & Ceramic Removal Equipment	Grazer StraBe 19-25, A - 8200 Gleisdorf, Austria Tel: 0043 3112 8000 Contact: Christian Makari E-mail: christian.makari@binder-co.at Web-site: www.binder-co.at
BJD Processing	Crushing Equipment	PO Box 21, Dewsbury Road, Wakefield, West Yorkshire, WF2 9BD Tel: 01924 201 740 Contact: Brian Beck E-mail: sales@bjdcrushers.co.uk Web-site: www.bjdcrushers.co.uk

BL-Pegson Ltd	Crushing Equipment	Fyne Avenue, Righead Industrial Estate, Bellshill, Lanarkshire, ML4 3LJ Tel: 01698 745 942 Contact: David Sheridan E-mail: sales@bl-pegson.com Web-site: www.bl-pegson.com
BOA Systems Ltd	Dust Control, Screening & Conveyor Equipment	12 Rorrington, Chirbury, Shropshire, SY15 6BX Tel: 01938 561 426 Contact: Graham Pike E-mail: recycle@boasystems.freeserve.co.uk Web-site: www.boanl.nl
Bollegraaf UK Ltd	Conveyors & Metal Removal Equipment	93-96 William Street, West Bromwich, West Midlands, B70 0BG Tel: 0121 557 9700 Contact: Greg Tierney E-mail: info@bollegraaf.co.uk Web-site: www.bollegraaf.co.uk
C.S.Bell	Crushing Equipment	Envirobanks, Ltd. Wales Tel: 01291 630 440 Contact: Mark Chapman E-mail: sales@csbellco.com Web-site: www.csbellco.com
Christy Hunt	Crushing Equipment	Foxhills Industrial Estate, Scunthorpe, North Lincolnshire, DN15 8QW Tel: 01724 280514 Contact: Steve Brooks E-mail: sales@christy-norris.co.uk Web-site: www.christynorris.co.uk
DBI Norclean Ltd	Dust Control Equipment	Meadowlands, Bilbury, Nr Cirencester, Gloucestershire, GL7 5LZ Tel: 01285 740 682 Contact: Alkis Petmezas E-mail: norclean@dbigroup.co.uk Web-site: www.norclean.no
DCE Ltd	Dust Control Equipment	Humberstone Lane, Thurmaston, Leicester, LE4 8HP Tel: 01162 696 161 Contact: S Berger E-mail: toritdce.uk@mail.donaldson.com Web-site: www.dce.co.uk

Donico	Crushing Equipment	1754 West 24Th Street, Erie, PA 16502+2127, USA Tel: 001 814 454-6000 Contact: John P. Donico E-mail: DonicoINtl@aol.com
Doppstadt (UK) Ltd	Screening Equipment	Unit 4 Murray Court, Hillhouse Industrial Estate, Hamilton, ML3 9SL Tel: 01698 307 172 Contact: Patricia Jennings E-mail: enquiries@doppstadt.co.uk Web-site: www.doppstadt.co.uk
Dust Control (Scotland) Ltd	Dust Control Equipment	6 Neil Street, Meadowside Industrial Estate, Renfrew, PA4 8SG Tel: 0141 886 3731 Contact: Stuart Daniel Lamont E-mail: stuart@dust-control.co.uk Web-site: www.dust-control.co.uk
EME	Crushing & Drying Equipment	Bernhard-Hahn-Str. 11-15, 41812 Erkelenz, Postfach 1456, 41804 Erkelenz Tel: 0049 02431 9618 0 Contact: Jens Rosenthal E-mail: rosenthal@eme.de Web-site: www.eme.de
Eriez Magnetics Europe Ltd	Metal Removal Equipment	Bedwas House Industrial Estate, Bedwas, Caerphilly, CF83 8YG Tel: 029 2086 8501 Contact: Paul Fears E-mail: eriez@eriezeurope.co.uk Web-site: www.eriez.com
Euro Recycling Company	Dust Control and Conveyor Equipment	175 Windsor Road, Carlton-in-Lindrick, Worksop, Nottinghamshire, S81 9DH Tel: 078 3127 0555 Contact: Graham B Lee E-mail: graham@redltd.co.uk Web-site: www.redltd.co.uk
Glass Aggregate Systems (GAS) – Formerly GAME	Crushing Equipment	Technical Engineering Services (UK) Ltd, Carlisle. Tel: 01228 525972 Contact: Howard Graham E-mail: tesukltd@yahoo.co.uk Web-site: www.glassagg.com
GEMCO Industries B.V.	Furnace Technology	P.O. Box 1713, 5602 BS Eindhoven, The Netherlands Tel: 0031 402 643 643 E-mail: info@gemco.nl Web-site: www.gemco.nl

General Kinematics Ltd	Conveyor & Screening Equipment	Dawley Brook Road, Kingswinford, West Midlands, DY6 7BB Tel: 01384 273 303 Contact: Alison Fowler E-mail: sales@generalkinematics.co.uk Web-site: www.generalkinematics.com
Gosford Recycling Equipment Ltd	Conveyor Equipment	1st Floor, Green House, Coningsby Close, Gosforth, Newcastle, NE3 5LN Tel: 0191 213 0484 Contact: Peter Newby E-mail: equipment2recycle@mre-uk.fsnet.co.uk Web-site: www.g-r-e.co.uk
Greenbank Technology Ltd	Drying Equipment	Philips Road, Whitebirk Industrial Estate, Blackburn, Lancashire, BB1 5PG Tel: 01254 690555 Contact: Geof Rossiter E-mail: info@greenbanktechnology.co.uk Web-site: www.greenbanktechnology.co.uk
Glass Recycling Technologies of Florida Inc. (GRTF) – Formerly Minpro	Crushing Equipment	4017 N Liberty St, Jacksonville, Florida, USA Tel: 001 905 319-8920 Contact: Paul Cooper E-mail: globalgrt@yahoo.com
Hazemag	Crushing & Drying Equipment	29 Woodthorpe Lane, Sandal, Wakefield, West Yorkshire, WF2 6JG Tel: 01924 251 760 Contact: Graham Mansfield E-mail: g.mansfield@hazemaguk.com Web-site: www.hazemaguk.com
HJ Digwood	Conveyor Equipment	Alveley Industrial Estate, Shropshire, WV15 6HG Tel: 01746 780 468 Contact: Nigel Hughes E-mail: sales@digwood.com Web-site: www.digwood.com
Horstmann Recyclingtechnik GmbH	Screening Equipment	PO Box 100565, Bad Oeynhausen, D-32505, Germany Tel: 0049 5731 7940 E-mail: recyclingtechnik@horstmann-group.com Web-site: www.horstmann-group.com
Hosokawa Micron Ltd	Drying & Screening Equipment	Rivington Road, Whitehouse Industrial Estate, Runcorn, Cheshire, WA7 3DS Tel: 01928 755 100 Contact: Barry Walmsley E-mail: powder@hmluk.hosokawa.com Web-site: www.hosokawa.co.uk

IMS Engineering Ltd	Crushing & Conveyor Equipment	Unit S1B, Tursdale Business Park, Tursdale, Co.Durham, DH6 5PG Tel: 0191 377 8880 Contact: Neil Johnson E-mail: ims-eng@talk21.com Web-site: www.imsengineering.com
Integrated Recycling Systems Ltd	Conveyor & Screening Equipment	Burnt Meadow Road, North Moons Moat, Redditch, B98 9PA Tel: 01527 65432 Contact: Derek Squires E-mail: sales@integratedrecycling.com
Kilburn	Drying & Conveyor Equipment	Subhash Nagar, Bhandup, Mumbai 400 078, India Tel: 0091 22 564 3101 E-mail: kilburn@bom3.vsnl.net.in Web-site: www.kilburnengg.com
Krysteline	Crushing & Drying Equipment	Rubis House, 15 Friarn Street, Bridgwater, Somerset, TA6 3LH Tel: 02380 45 23 42 Contact: Steve Wettingsteel E-mail: steve.w@krysteline.net Web-site: www.krysteline.net
Lightning Crushers	Crushing Equipment	Kings Road, Halstead, Essex, CO9 1HD Tel: 01787 474 547 Contact: Dean McGivern E-mail: sales@lightning-crushers.co.uk Web-site: www.lightning-crushers.co.uk
Magco Tollemache Ltd	Crushing, Screening and Conveyor Equipment	County Estate, Sutton-in-Ashfield, Nottinghamshire, NG17 2HW Tel: 01623 440 990 Contact: Denby Slingsby E-mail: denby.slingsby@langley-group.co.uk Web-site: www.magco-tollemache.co.uk
Master Magnets Ltd	Metal Removal Equipment	Magnet House, 251 Alcester Road South, Kings Heath, Birmingham, B14 6DT Tel: 0121 444 4266 Contact: Joe Cetti E-mail: joe.cetti@mastermagnets.co.uk Web-site: www.mastermagnets.co.uk

Metal Detection Ltd	Metal Removal Equipment	Barnfield Industrial Estate, Ramsay Road, Tipton, West Midlands, DY4 9DW Tel: 0121 557 2104 E-mail: sales@metaldetection.co.uk
Metso Minerals (UK) Ltd	Crushing & Screening Equipment	Parkfield Road, Rugby, Warwickshire, CV21 1QJ Tel: 01788 532 100 Contact: Chris Tressler Web-site: www.metso.com
Mist-Air Dust Sepression	Dust Control Equipment	PO Box 10, Oswestry, Shropshire, SY10 9JF Tel: 01691 828 487 Contact: Mike Carter E-mail: info@mist-air.co.uk Web-site: www.mist-air.co.uk
Mitchell Dryers Ltd	Drying Equipment	Denton Holme, Carlisle, Cumbria, CA2 5DU Tel: 01228 534433 E-mail: info@mitchell-dryers.co.uk Web-site: http://home.btconnect.com/mitchell-dryers/
Mogensen	Conveyor & Screening Equipment	Harlaxton Road, Grantham, Lincolnshire, NG31 7SF Tel: 01476 566 301 Contact: Bruce Donaldson E-mail: sales@mogensen.co.uk Web-site: www.mogensen.co.uk
MSS	Colour Sort, Ceramic Sort, Metal Removal Equipment	PPS Recovery Systems Ltd, 9 Metro Centre, Welbeck Way, Woodston, Peterborough, PE2 7WH Tel: 01733 390 029 Contact: Ian Smith E-mail: ian.smith@pps-ltd.com Web-site: www.magsep.com
Nicholls Air Systems Ltd	Dust Control Equipment	1-4 Enterprise Park, Hunters Road, Weldon North Industrial Estate, Corby, Northamptonshire, NN17 5JE Tel: 01536 400 234 Contact: Roger Wright E-mail: roger.wright@nichollsair.co.uk Web-site: www.nichollsair.co.uk
O Kay Engineering Services Ltd	Conveyor, Screening & Metal Removal Equipment	Valley Way, Market Harborough, Leicestershire, LE16 7BS Tel: 0800 731 8274 Contact: Antonia Kay E-mail: postbox@okay.co.uk Web-site: www.okay.co.uk

Peak Separation Equipment Ltd	Metal Removal	Unit 2 Temple Normanton Business Park, Mansfield Road, Corbriggs, Chesterfield, Derbyshire, S41 0JS Tel: 01246 220 552 Contact: Paul Kittrick E-mail: peaksep@aol.com
Portable Conveyors Ltd	Crushing, Conveyor & Screening Equipment	Bowling Green Lane, Albrighton, Wolverhampton, WV7 3HB Tel: 01902 373 735 Contact: Phil Shakesheff E-mail: enquiries@portable-conveyors.co.uk Web-site: www.portable-conveyors.co.uk
Portsdown Engineering	Bagging Equipment	227B West Street, Fareham, Hampshire, PO16 OHZ Tel: 01329 232300 E-mail: portsdown@freeuk.com Web-site: www.portsdown.freeuk.com
Prodeva	Crushing Equipment	100 Jerry Drive, Jackson Center, Ohio 45334-0729, USA Tel: 001 937-596-6713 Contact: Steve Bunke E-mail: sbunke@prodeva.com Web-site: www.prodeva.com
Pulverisers & Shredders Ltd	Crushing Equipment	Waterloo Works, Trafalgar Street, Burnley, Lancashire, BB11 1RF Tel: 01282 422 754 Contact: Diana Fairburn E-mail: pipeprofiling@compuserve.com Web-site: www.pulverisers.com
S+S	Colour Sort & Ceramic Removal Equipment	Regener Straße 130, D-94513 Schönberg, GERMANY Tel: +49 (0)8554 3080 Contact: Peter Mayer E-mail: info@ss-gmbh.de Web-site: www.ss-recycling-technic.com
Stordy Combustion Engineering Ltd.	Drying Equipment	Heath Mill Road, Wombourne, Wolverhampton, WV5 8BD Tel: 01902 891200 E-mail: sales@stordy.co.uk Web-site: www.stordy.co.uk
Ventilex USA Inc.	Drying Equipment	2960 Robertson Avenue, Cincinnati, Ohio 45209, USA Tel: 001 866 265 6823 E-mail: info@ventilex.net

		Web-site: www.ventilex.net
Walker Magnetics UK	Metal Removal	Units 4 & 5, Firbank Court, Firbank Way, Leighton Buzzard, Bedfordshire, LU7 4YJ Tel: 01525 372714 E-mail: wmuk@walkermagnet.com Web-site: www.walkermagnet.com/uk
Waste Mechanics Ltd	Screening & Conveyor Equipment	Downs Works, Glemsford, Sudbury, Suffolk, CO10 7PH Tel: 01787 282 774 Contact: Alan Valentine E-mail: sales@wastemechanics.com Web-site: www.wastemechanics.com
Wendt	Metal Removal	2080 Military Road, Tonawanda, NY, 14150-6765 USA Tel: 001 716 873 2211 E-mail: sales@wendtcorp.com Web-site: www.wendtcorp.com

11. Appendix 3 UK Market Development Network

Organisation	Contact Details
ReMaDe Scotland	Drummond House (3rd Floor) 1 Hill Street Glasgow G3 6RN Tel: 0141 582 0450 Fax: 0141 582 0451 Web: www.remade.org.uk
ReMaDe London	1 Hobhouse Court Suffolk Street London SW1Y 4HH Tel: 020 7665 1536 Fax: 020 7665 1501 Web: www.londonremade.com/london_remade
ReMaDe Essex	Carlton House 31/34 Railway Street Chelmsford Essex CM1 1NJ Tel: 01245 492858 Fax: 01245 259366 Web: www.remadeessex.org.uk/Remadedetails.htm
ReMaDe Kernow	Unit 1, the Courtyard Trewolland Liskeard Cornwall P14 3NL Tel: 01579 349 316 Fax: 01579 340 406 Web: www.cwwg.co.uk/menu/default.asp?p=remade
ReMaDe South West Ltd	Tel: 01392 683515 Contact: David Chambers E-mail: davidchambers@blueyonder.co.uk
ReMaDe Kent and Medway	c/o Invicta Innovations Horticulture Research International East Malling Kent ME19 6BJ Tel: 01732 876617 Fax: 01732 876611 Web: www.remade-kentmedway.co.uk/remade/index.html
Waste & Resources Action Programme (WRAP)	The Old Academy 21 Horse Fair Banbury Oxon OX16 0AH Tel: 0808 100 2040 Fax: +44-1295 819911 Web: www.wrap.org.uk
Clean Merseyside Centre	Clean Merseyside Centre Unit 36B, The Colonnades Albert Dock Liverpool L3 4AA

	Tel: 0151 708 9533 Fax: 0151 707 2431 Web: www.clean-merseyside.com
Hampshire County Council	Ashburton Court West Winchester Hampshire SO23 8UD Tel: 01962 846802 Fax: 01962 847055 Web: www.hants.gov.uk
Wales Environment Trust	Tredomen Business and Technology Centre Ystrad Mynach Caerphilly South Wales CF82 7FN Tel: 01443 866 300 Fax: 01443 866 301 www.walesenvtrust.org.uk
Enviros	20 - 23 Greville Street Farringdon London EC1N 8SS Tel: 0207 421 6340 Fax: 0207 430 2210 Web: www.enviros.com
Urban Mines	The Cobbett Environmental Enterprise Centre Village Street Norwood Green Halifax HX3 8QG Tel: 01274 699400 Fax: 01274 699410 Web: www.urbanmines.org.uk