

REUSE/RECYCLING OF GLASS CULLET
FOR NON-CONTAINER USES

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Reuse/Recycling of Glass into Other than Glass Bottles

The markets for glass container cullet can be broadly thought of in two main categories: (1) new glass containers, and (2) all other uses. While the glass container manufacturers can theoretically use all the color sorted cullet collected to make new containers, for many communities, there are significant barriers of transportation cost and the problem of either marketing mixed colors, or, more recently, having them processed with electro-mechanical glass sorting equipment. On the other hand, the recovery of glass for non-container uses has been growing rapidly, in fact, much faster than the recovery of glass to make new containers, as shown in the next table:

US Glass Recovery, in Tons

| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1992-1998 change |
|---|------------------|------------------|------------------|------------------|------------------|------------------|------------------|---------------------|
| Cullet purchases by the glass industry | 2,439,782 | 2,432,463 | 2.5 million | 2,440,313 | 2,530,942 | 2,309,310 | 2,338,329 | -4.2% |
| Refillables | 747,081 | 859,143 | 832,000 | 606,312 | 506,880 | 423,760 | 467,424 | -37.4% |
| Non-container uses | 450,000 | 575,000 | 641,000 | 701,213 | 643,190 | 613,631 | 603,608 | 34.1% |
| Total | 3,640,000 | 3,870,000 | 3,970,000 | 3,747,838 | 3,681,012 | 3,346,701 | 3,409,361 | -6.3% |

(1992 is the first year that the GPI data for cullet purchases includes the entire industry. 1998 usage of glass was 9.23 million tons of domestically produced containers and 0.56 million tons of imported containers.)

The Glass Packaging Institute has discontinued the collection of recycling data, but according to the article "Profiles in Garbage. Glass Containers", in Waste Age in February, 2003, the glass recovery rate in the US is approximately 26% (http://wasteage.com/ar/waste_glass_containers/index.htm).

Sources: Bottle/Can Recycling Update, April 1994, page 3; Recycling Times, May 16, 1995, page 12; June 1, 1998, page 35; Glass Packaging Institute Web Page (<http://www.gpi.org>), November 19, 1995; May 28, 1996; May 18, 1997, and personal communication, October 28, 1999. In a search on January 4, 2001, there were no recycling data on the GPI web page. And in an email note on January 9, 2001, GPI said that they had not contracted to collect the recycling data for either 1999 or 2000.

This database is a compilation of information of alternatives for reusing and recycling glass, especially glass bottles and jars. The information was gathered from state and provincial governmental agencies of the US and Canada, as well as the respective state and provincial recycling organizations, and from articles from magazines and conferences.

This database builds upon the Glass Markets Information System prepared by the Washington State Department of Trade and Economic Development Clean Washington Center, which is now known as CWC. The Glass Markets Information System lists both potential and actual markets for glass cullet, as well as potential application to the State of Washington.

The Glass Markets Information System has eight main categories, and, within each category, individual classes. The eight categories are:

- Bottle Applications
- Building Materials
- Concrete Applications
- Construction Aggregates
- Industrial Mineral Uses
- Insulation Applications
- Paving Applications
- Remelt Applications
- Miscellaneous Applications

Undoubtedly, my use of their classification system is somewhat different than what might have been done by the Clean Washington Center, and I may have classified projects differently than the originators. Also, the borders between the different categories and classes are not always sharply defined, and a given use may be rightfully classified several ways. Finally, I have not included any descriptions where glass bottles are reused or recycled back into glass bottles; all the uses listed are for non-container applications. Given these limitations, it is hoped that the common use of this Clean Washington Center classification will facilitate the sharing of information.

Copies of the summary reports of Glass Markets Information System and detailed technical reports are available from the Clean Washington Center, telephone (206)443-7746, or 999 3rd Avenue, Suite 1060, Seattle, WA 98104. In addition, reports are being placed on the Clean Washington Center Web Page at <http://www.cwc.org>.

I thank everyone who provided information for this database and encourage others to both provide suggestions on how to make this database more useful as well as information on other uses for reusable or recyclable glass. By sharing information on alternatives, markets can be improved for everyone. Especially important are the continued activities of CWC. When they were part of the state government in the State of Washington, their strategic plan for 1995 and 1996 for the development of markets for glass and are part of the Recycling Technology Assistance Partnership (ReTAP) included a manual on the best practices in glass is being prepared. As of November, 1996, the list of topics for this was as follows:

Topics List
Best Practices Manual for Recycled Glass
Clean Washington Center
1996

I. Sourcing

1. Evaluating Recycled Glass Supply Streams
2. Controlling Breakage in the Collection of Glass
3. Typical Contaminants in Recycled Glass
4. Chemical Composition of Container Glass

II. Processing

A. Fine Sizing

1. Fine Sizing of Recycled Glass
2. Dust Control Strategies for Processing
3. Recovering Glass Fines Through Drying
4. Costs of Small-Scale Glass Fines Processing
5. Conveyor Technologies for Glass Processing
6. Selecting Crushing Equipment to Minimize Wear
7. Analysis of Glass Dusts
8. Sizing Glass for Industrial Mineral Applications

B. Sorting & Screening Technologies

1. Automated Color-Sorting of Glass
2. Manual Sorting Protocols
3. Using Trommel Screens
4. Using Vibratory Screens

C. Contamination

1. Magnetic Separation Technologies for Glass Processing
2. Non-ferrous Separation Technologies for Glass Processing
3. Removing Ceramic Contaminants
4. Moisture Control Strategies for Glass Processing

D. Windshields

1. Processing Automobile Windshield Glass

E. Construction Aggregate

1. Strategies for Crushing & Screening Glass Aggregate

III. Product Manufacturing

A. Bottle Washing

1. Elements of a Bottlewashing Operation
2. Removing Label Adhesives in Bottlewashing

B. Art Glass

1. Using Recycled Glass in Art Glass Applications
2. Strategies for Color Modification of Recycled Glass

C. Container/Fiberglass Manufacturing

1. Sampling and Testing Products for Recycled Glass
2. Recycled Glass and Furnace Energy Usage
3. Cullet Specifications for Container Manufacturing
4. Cullet Specifications for Fiberglass Manufacturing
5. Developments in use of Mixed-Color Glass
6. CBOT Recyclables Exchange Protocols
7. Container Coatings and Glass Recycling

D. Fusing

1. Organic Binders for Recycled Glass Tile Manufacturing
2. Calcium Aluminate Cement Binders for Recycled Glass Fusing
3. Fusing Recycled Glass
4. Simple Particle Packing
5. A Simple Vibratory Compaction Table

IV. End-Use Applications

A. Industrial Minerals

1. Using Recycled Glass in Abrasive Blasting
2. Selecting Appropriate Supply for Industrial Fillers
3. Using Glass in Paint

B. Filtration

1. Using Glass as a Septic Filtration Medium
2. Using Glass in Water Filtration

C. Construction Aggregates

1. Sampling Procedures for Construction Aggregate
2. Developing Specifications for Aggregates in Structural Fill
3. Visual Inspection of Glass Aggregates
4. Specifications for Cullet Aggregate
5. Dust Control with Glass Aggregate at Construction Sites
6. Compaction of Glass Fill
7. Density Test of Glass Aggregate Using Nuclear Densometer
8. Moisture Content Test of Glass Using Nuclear Densometer
9. Structural Fill Applications
10. States with D.O.T. Specifications for Glass Aggregate
11. General Fill Applications for Recycled Glass

D. Bound Applications

1. Using Glass with Epoxy Binders
2. Glassphalt

V. Internet

1. Information Links

For more information on this manual, contact CWC at (206)443-7746, or write to them at 999 3rd Avenue, Suite 1060, Seattle, WA 98104.

Updates of this database are available from the author at no cost, either by regular mail, or by email. Also, the author welcomes information on additional projects or further information on the projects listed.

In addition, readers are encouraged to access the report "Reusing and Recycling Glass in Manitoba. Challenges & Opportunities. September 2000", prepared by the Manitoba Product Stewardship Corporation and on the Internet at <http://www.mpsc.com/web/resources/GlassReport.pdf> (accessed April 16, 2003). The report includes specifications for the reuse of glass for non-container uses and lists over 130 projects in Manitoba (with contact information), as well as providing summaries of several projects.

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{Note: the page numbers in the electronic edition of the table of contents may be slightly incorrect, due to updates in the database that are not yet reflected in the page numbers.}

The Chemistry of Glass Bottles

For some of the methods of reusing or recycling glass containers, the chemistry of the glass is critical. The information provided here is somewhat general, but should be of assistance for those uses which depend on the chemical composition.

The glass container industry in the United States in 1995 is estimated to have annual sales of some \$5 billion, selling 41 billion containers produced at 68 manufacturing facilities. On a color basis, 63% are clear, 25% are amber, 10% are green and 2% are blue or other colors. The Freedonia Group Inc. forecasts that glass container sales will remain flat or slightly decline through the year 2000. The largest glass manufacturer in the US is Owens-Illinois, with 40% of the market, followed by Ball-Foster with 26% of the market and closely followed by Anchor with 25%.

In the December 1997 issue of Glass Industry, a summary of a paper given at the 1996 Glass Problems Conference by Paul Guttman, Director of Sales for U.S. Silica puts the gross consumption of materials for glass manufacture at:

North American Raw Material Consumption for Glass Manufacture

| Material | Tons |
|------------------------|------------|
| Sand | 12,000,000 |
| Soda ash | 4,000,000 |
| Limestone and dolomite | 1,750,000 |
| Alumina minerals | 750,000 |
| Cullet | 3,000,000 |

In the 1972 edition of The Glass Primer, Dr. Harry Hoscher, published by Magazines for Industry, Inc., the publisher of the magazine, The Glass Industry, the composition of uncolored glass containers is given as the following:

| Material (Weight Basis) | Composition |
|--------------------------------|-------------|
| SiO ₂ | 71.5-73.5% |
| Na ₂ O | 12.5-15.5 |
| CaO | 7.8-10.8 |
| MgO | 0.1-3.6 |
| Al ₂ O ₃ | 0.4-2.2 |
| K ₂ O | 0.4-1.0 |
| BaO | 0.0-0.5 |
| B ₂ O ₃ | 0.0-0.2 |
| Fe ₂ O ₃ | 0.04-0.05 |

However, as with other products, the composition of glass containers has changed over the years and is still changing. In the article "How Composition Affects Workability" (The Glass Industry, July 1991, pages 13-14, 26), Anup Sircar of Evanite Fiber Corporation notes that manufacturers are changing the composition of their mixes both to save money on raw material costs as well as to achieve processing benefits. The trend appears to be a lowering of Na₂O (to about 11.0 to 12.0% in Europe) with a partial increase in MgO, and a lowering of Al₂O₃ (to about 1.2% from 2.2%). The author notes that US manufacturers are often still at the higher range of Na₂O, or about 14.5%. With the increase of Na₂O (soda ash) prices from \$72 a ton to \$140 a ton over the previous 10 years, and an increase in Al₂O₃ (feldspar) prices from \$25 a ton to over \$50 a ton in the same time period, the author notes that reformulation of US glass to lower quantities of these materials will save the manufacturers money without a

sacrifice in chemical resistance or durability of the glass, while at the same time increasing the cooling time, and increasing the relative machine speed.

Another change that is occurring in the glass industry is the increased use of lithium salts. These materials improve the manufacturing process for glass containers by improving the fluxing of the glass, decreasing the viscosity, reducing the melting temperatures, increasing furnace throughput and increasing the percentage of containers shipped.

The magazine The Glass Industry has updates of raw material supplies in its December issue each year.

For the recycling of glass cullet into glass bottles, the following limits are put on the composition of the cullet by one recycler, Consumers Glass Company, Limited:

Post-Consumer Cullet Composition

| Material | Amber | Emerald Green | Flint |
|--------------------------------|------------|------------------|------------|
| SiO ₂ | 71.4-73.2% | 71.5-73.1% | 71.6-74.3% |
| R ₂ O | 12.5-15.1 | 13.7-14.9 | 13.0-14.7 |
| RO | 7.6-11.3 | 10.3-11.0 | 10.2-11.6 |
| Al ₂ O ₃ | 1.3-2.4 | 1.6-2.0 | 1.5-2.3 |
| Be ₂ O ₃ | 0.22-0.46 | 0.12-0.20 | 0.03-0.10 |
| TiO ₂ | 0.02 | 0.02 | 0.02 |

Note: Generally, R₂O is either Na₂O or K₂O, while RO is from the group CaO, MgO, SrO, or BaO

Source: Resource Recycling, March/April 1986, page 20

Equipment to Mechanically Sort Glass by Color and/or Remove Contaminants

As an alternative to marketing mixed-color glass, technology is available to sort mixed color glass into the various colors. Some systems will only separate one color per pass; other systems provide sorts into multiple color streams. This list is an alphabetical summary of known systems.

1. Alpine Technology, Eugene, Oregon

The development of this system was financially supported by the US Department of Energy and the State of Oregon Department of Energy. Progress reports are available from the National Technical Information Service (NTIS) for October 1, 1993 to September 30, 1994.

According to an article in Resource Recycling's Bottle/Can Recycling Update, March 1995, Pennsylvania Cullet Processing Center in Corsica has purchased this system, and found that it did not work. The system could neither handle the quantity of material nor meet the separation efficiency given in the specifications.

2. Bezner System, Germany

According to an article in Resource Recycling's Bottle/Can Recycling Update, March 1995, the materials recovery facility operated by Resource Recovery Technologies for the Rhode Island Solid Waste Management Corporation will be installing a Bezner system to color sort glass, with operation expected by the end of 1995. The system is said to have been operational in Europe.

3 Binder, Austria

According to an article in Glass (volume 70, number 3, page 113, March 1993), the Austrian firm Binder + Co AG of Gleisdorf has developed a glass color sorting machine that is in use at the German Bundesfachverband für Glas. The separator is designed to handle glass in sizes of 8 to 60 mm, and has a throughput of 5-10 metric tons per hour. Contamination levels are as follows:

| Sorted Glass color | Allowable Contamination | | |
|-----------------------|-------------------------|-------|-------|
| | Clear | Brown | Green |
| Clear | - | 0.5% | 0.1% |
| Brown | 5% | - | 5% |
| Green | 5% | 5% | - |

In a 1994 article in Glass, (volume 71, number 7, pages 261+, July 1994), a Binder system is described in Velten, Berlin, Germany, where 40 metric tons of cullet are processed per hour, with an annual production of 250,000 metric tons. The system includes equipment to remove contaminates (the KSP separators handle ceramics, stones and porcelains and over 300 sold have been sold), as well as color sorting equipment, known as BWG (Brown-White-Green) color separators.

4. BMA, Lederer & Associates, Jacksonville, FL

The BMA technology both removes contaminates as well as color sorts the glass. In the literature provided (not dated, but received in 1995), a description of the opportunities, standards and cost of a system in Germany are described. Detection is with optical readers and inductive measuring devices. [I suspect that this is really a German made machine that is being sold in the US by Lederer & Associates.]

5. Exner-Werth, Langelsheim, Germany

The Exner-Werth machine separates glass both by individual color and removes contamination, using a detection system based on light, in which material to be separated slides down a trapdoor to the proper conveyor line. When I visited this facility in February 1997, the machine was operational and processing

glass on an on-going basis. The firm was not yet marketing their technology to other users, but expressed interest in looking into this option.

6. Falcon United Ltd.

This firm has received patents (5,350,121 and 5,246,174) for a process to separate glass components of articles composed of glass and non-glass materials by subjecting the articles to controlled vibrations that break the glass, while not breaking the non-glass components. The glass is then screened from the non-glass material. [Abstract only reviewed.]

7. Magnetic Separation Systems, Inc, US

In an article in the July 1994 issue of Glass (volume 71, number 7, page 265), the equipment of MSS is described to remove metallic and ceramic contaminants from cullet.

For metal removal, the removal efficiency is said to exceed 98% with less than 1% product loss. The equipment comes in 12 and 25 tons/hour capacities.

The ceramic removal equipment builds upon the Elke removal system developed by Siemens AG. Ceramics down to 3/8 inch can be removed, with a removal efficiency of greater than 90%, and a product loss of less than 1%. Two sizes of equipment are available; 12 and 25 tons per hour.

MSS has also developed a system to sort glass by color, known as Glass ColorSort.

The firm has developed systems of 5, 15 and 40 tons an hour capacity, according to its first quarter, 1998 newsletter known as The Sorter.

The web page for MSS is <http://www.magsep.com>, and email at magsep@magsep.com.

8. Maltha, Holland

According to an article in Glass (volume 70, number 7, page 267, July 1993), the Dutch recycling company Maltha has built a new recycling plant that will handle 200,000 tonnes of cullet a year. The firm has developed technology to sort the glass by color and to remove contaminants. Final specifications are for ferrous metal and non-ferrous metal to each be less than 25 grams per tonne (0.0025%), lead below 50 g/tonne (0.005%), and ceramics at less than 125 g/tonne (0.0125%). The plant was scheduled to have a formal opening in September 1993.

9. Mitsubishi Heavy Industries Ltd, Tokyo

In the 1995/6 International Directory of Solid Waste Management, there is a short article describing Mitsubishi's machine that can sort 2 to 4 tons per hour into the colors of clear, brown, green and light blue, and black, along with a discharge for other materials. The system is said to use a CCD camera to identify the different types of glass, and that "The system's accuracy is almost equal to that of the manual method".

10. S & S Electronics /S+S Metallsuchgeräte und Recyclingtechnik GmbH, Germany

An article in Glass (volume 70, number 3, pages 109, 111-112, March 1993), describes the experience of a Dutch firm in using a stone sorting machine developed by S+S Electronics, Schönberg, Germany to automate their glass handling. The sorter was included in the middle of an 8-step processing system, and follows two magnetic removals, a hand sort and air classification. The cullet had been screened to remove all material less than 10 mm in size. Recovery results varied depending on the hourly throughput, the level of contaminants, cullet size and size distribution, weather and other factors. The authors look for further improvements in system effectiveness.

An article in the July 1994 issue of Glass (volume 71, number 7, page 259), describes a machine recently developed by the firm to color sort glass and remove contaminants using lasers. The machine is said to be able to sort cullet over 4 mm in size, with a capacity of 12-15 metric tons per hour.

An article in Glass Industry (February 2000, page 22) says that the latest machines can separate out contaminants as small as 2 mm in size, with very low glass losses.

11. Societa' per L'Elettronica Applicata (SEA), Villanova, Italy

In Glass (volume 70, number 3, page 118, March 1993), an article says that SEA has five models of sorting machines for glass, ranging from 4 tons an hour to 20 tons an hour, which both sort glass by color as well as removing ceramics, stones, metal and other contaminants. As of 1993, 40 machines have been installed in Europe in various industries.

In an article in the July 1994 issue of Glass (volume 71, number 7, page 265), an improved machine is described, with the electronics operating at 10 times the previous system. Ceramic removal is guaranteed at 94% for a single pass, a 99% removal of color glass from clear glass and a 90% removal of clear glass from green or brown glass.

According to a grant application to the University of Wisconsin recycling program in the fall of 1995, SEA is said to have a machine that can both color sort glass and remove contaminants, with a capacity of 20 tons per hour. Although none of these machines are said to be in operation in the US, 80 of these machines are said to be in operation in other countries.

In Recycling Times of May 1, 1996, an article says that the Rhode Island Solid Waste Management Corporation was purchasing an SEA system for their MRF. The system will work on glass that is between 5/8" and 2", with larger pieces hand separated and smaller pieces marketed as mixed color cullet.

In the June 1996 issue of Resource Recycling, a short article said that Countec of Des Moines, Iowa is the exclusive US representative for this equipment. In the March 1997 issue of Waste Age, a description is provided of the use of this system in the Baltimore, MD Resource Recovery, Inc. plant. Said to be the size of a long bookcase, the \$280,000 machine is said to be able to color sort mixed color cullet to meet very tough European standards. The system can separate glass by color, remove non-glass contaminants, or do both. However, it separates into only two streams at a time; multi-color streams need to be run through the system multiple times.

12. Sortex Company of North America

In a March 1974 report from the Institute for Environmental Studies at the University of Wisconsin-Madison, a description is given of a machine to sort glass by color. The machine uses photocells to detect the various colors and an air stream to separate the individual pieces. Originally built to separate bad rice from good rice, the machine is said to be able to process glass in sizes of 3/16 inch to 2 inches. The capacity of the machine is given at 3,000 pounds per hour, using 6 feed channels. Capital cost is put at \$21,500, with \$1,600 per year for labor.

13. US Bureau of Mines

A 1971 report of the US Bureau of Mines describes a system it developed for the electronic color sorting of glass. Starting with a mixture of 54% clear glass, the separator produced a stream that had 86% clear glass, and recovered 62% of the clear glass. (Electronic Color Sorting of Glass from Urban Waste, PB 205 739)

14. University of Illinois, Urbana

In 1991, the University of Illinois was working on a machine to optically color sort glass. In laboratory tests, they achieved a 98% purity level for clear glass and a 76% purity level for the colored outputs when using an

infected of 60% clear and 40% colored glass. A letter was sent to the researchers on December 22, 1995 to obtain updated information.

15. Unknown

In an annotation of an article in the magazine Glastechnische Berichte (volume 68, number 5, pages N63-N69, 1995), a glass processing system to grind glass -- while simultaneously removing contaminants -- is described. Contaminants are removed because the process only grinds the glass, while not grinding the non-glass materials. It is said that several machines have been in operation in the US since 1991, and pilot plants are being installed in Europe to confirm this trend.

15. Unknown

In an article in Glass Technology, (volume 35, number 2, pages 56-57, April 1994), it says that laser sorting equipment is used in Europe (especially in Germany) to remove impurities from recyclable cullet. [Compiler's note: this may include several brands of equipment.]

16. Unknown

According to an article in Glass (volume 70, number 3, page 121, March 1993), the largest glass recycling firm in the UK, Berrymans, has invested in an automated processing system, including an electronic scanner to color sort cullet and remove contaminants. Handling 20 metric tons an hour, the machine reduces the organic content to 0.3%, ceramic and non-magnetic content to 0.002% and magnetic content to 0.005%. In addition, it can detect green glass to a level of 0.5%. The name of the manufacturer is not given.

17. Un-named individual

Patent 5,333,797 is for a device to separate contaminants from glass for recycling. Ferrous metals are removed by a magnetic belt and vibratory screen, light and heavy materials are separated by a finger screen air knife and vibratory screen followed by manual sorting, and a trommel screen is then used for separating other contaminants and to reduce the glass to a size that can be used in glassphalt or aggregate. [Abstract only reviewed.]

18. Zippe Industrieanlagen GmbH, Wertheim, Germany

In an article in the January 1996 issue of Glass Machinery Plants & Accessories, Zippe describes their system to both remove contamination and to color separate glass.

Contamination removal is by a multi-stage process of crushing and screening the cullet to remove oversize contaminants, removal of ferrous metals with a magnet, vacuuming off light materials using an eddy-current separator to remove non-ferrous metals, ceramic removal via light detection and pneumatic removal, followed at the end by color "improvement" with an undescribed system.

In addition, another system available from Zippe attacks the ceramic contamination problem by fine grinding cullet, which precludes the need to remove all ceramic contaminants.

19. EME Maschinenfabrik Clasen GmbH, Erkelenz, Germany. http://www.eme.de/recycling_english.html; accessed July 18, 2003

According to company literature provided in 1997 and a web search in 2003, EME provides glass cullet recycling systems to pulverize cullet and remove metal, paper, plastics, dirt and ceramics. The company has produced equipment for the glass industry for over 75 years.

Scrap Glass Exports

In recent years, the export markets for scrap glass from the US have increased dramatically, although they are still small in comparison to the overall quantity of scrap glass recycled. For example, in 1997, an estimated 55,000 tons of glass cullet were exported for recycling, while 3 million tons were recycled in the US. And in the July 1999 issue of Resource Recycling, it notes that NexCycle, Inc of Irving, Texas has exported more than 100,000 tons of glass cullet from the US in the last two years, with shipments to Central and South America, the Caribbean, and continental Europe.

The data on scrap glass exports from the US are confusing. For example, in the February 1998 issue of Resource Recycling, the exports of scrap glass for the US for the first 10 months of 1997 was put at 53,900 tons, with an average value of \$142.89 per ton, for a total value of \$7.7 million.

However, in the March 1998 issue of Recycling Today, it is reported that some 17,000 tons of scrap glass were exported from the US in the first 10 months of 1997, with a total value of \$80.3 million, or a value of over \$4,700 a ton.

Besides great differences in the total tonnages and the values, neither of these data on the value of the glass appear reasonable. As noted in the section on glass recycling in Europe, even in Italy, which has a strong demand for glass, high quality glass had a value of \$80 to \$100 a ton in 1996, nowhere near the values quoted above. For comparison, in the January 5, 1998 issue of Recycling Times, the average values for glass cullet paid by end users were fell from \$41.20 a ton in January for flint down to \$34.60 a ton in December, \$36.10 a ton for amber in January to \$29.20 a ton for amber in December, and for green, from \$15.70 a ton in January to \$11.20 a ton in December.

No published information on the use of exported cullet has been located by this author. In discussions with exporters, they are also not willing to share specific information. However, in a February 1998 email message with Maurizio Cappello of Italy (mcappello@mail4.clio.it), who is involved in researching other uses for recycling glass, he says that the main usage of glass cullet imported from the US is to make glass containers.

In a December 1997 article in Glass Industry, it was noted that three countries dominate the export market for cullet: the United Kingdom (46%), Italy (33%), and Mexico (14%). Glass exports for the first three months of 1997 reached 28,000 tons, 6 times the amount exported in the first 3 months of 1996, and just short of the amount exported in all of 1995, the record year for cullet exports. In addition, the article said that Strategic Materials was shipping green glass to Puerto Rico, Trinidad, Tobago, Mexico and Argentina. The role of Italy is shown in the December 1997 issue of Resource Recycling, where it is noted that Internat Glass of Montreal, Canada has exported more than 50,000 tons of glass to Italy in the previous 18 months. No information has been found on the exporting of cullet to the United Kingdom.

One of the constraints for exporting glass is the cost of shipping. In the above referenced article in the December 1997 issue of Resource Recycling, it was noted that the strong US dollar resulted in shipping costs to Italy of \$25-\$30 a ton. A second constraint is the increased competition from other countries, which are increasing their collections of glass containers for recycling.

Besides the exports from the US, the article from Recycling Today has information on scrap glass imports into the US. For the first 10 months of 1997, the total is given as 118,400 tons worth \$391 million, for an average per ton value of over \$3,300. The author of this article was been contacted about these values and is trying to determine why the import and export values shown earlier are so high on a per ton basis.

Glass Recycling in Europe

In the European Union, a Directive (94/62) has been established for the recycling of packaging, including glass.

One of the standards of the directive is a target rate of 15% recycling and recovery of glass, with a maximum rate of 45% unless indigenous facilities exist to handle the material collected.

All (western) European countries exceeded the minimum of the Directive as of 1994, and several exceed the maximum level, with Switzerland topping the list at 92% as shown in the table below.

European Glass Recycling: 2001¹

| Country | Tonnes | Recycling Rate |
|----------------|-----------|----------------|
| Austria | 200,000 | 83% |
| Belgium | 279,000 | 88% |
| Denmark | 125,000 | 65% |
| Finland | 46,000 | 91% |
| France | 1,950,000 | 55% |
| Germany | 2,666,000 | 87% |
| Greece | 44,000 | 27% |
| Ireland | 46,000 | 40% |
| Italy | 1,100,000 | 55% |
| Netherlands | 400,000 | 78% |
| Norway | 44,000 | 88% |
| Portugal | 122,000 | 34% |
| Spain | 506,000 | 33% |
| Sweden | 144,000 | 84% |
| Switzerland | 294,000 | 92% |
| Turkey | 73,000 | 24% |
| United Kingdom | 736,000 | 34% |
| Total | 8,775,000 | |

¹ Internationalt Affaldsnyt, Number 1, February 2003, <http://www.affaldsinfo.dk/user/1007/4379.pdf>. These same data are also available on the web page of the German organization, glas aktuell, <http://www.glasaktuell.de/frameset.php3>

(Data apparently include recycled glass only; and not also refilled containers.)

Most of the collected glass is remade into glass bottles and jars, with the European Glass Container Federation (FEVE) estimating that well over 90% of the cullet is recycled back into bottles. However, it is recognized that as glass recycling increases, there may be a need to expand alternative uses. Further, in a July, 1994 article in the British magazine, Glass, the UK's glass trade association, British Glass, notes that because of imports of products in green glass, there is a problem with an excess of green glass being collected at the bottle banks, which necessitates the development of alternative markets for both green glass, as well as contaminated cullet. British Glass has been working on alternative uses for cullet since 1991.

According to FEVE's September 1995 newsletter, Glass Gazette, most European countries collect glass at drop-off centers, or "bottle-banks", and the use of these systems is growing rapidly. In the September, 1996 issue of Glass Gazette, an article on the collection of glass in France noted that 86% of all glass was collected in bottle banks, compared to 14% curbside. A study found that curbside collected glass had significantly more degradation than bottle bank collected glass, and recommended expansion of the bottle bank program. France was at a 50% recycling rate for glass, and has a goal for 75% recovery in 2002.

Another reason for the use of bottle bans is to maintain color separation. For example, in Germany, mixed color glass accounted for 45% of all glass collected in 1993 until additional bottle banks were established, reducing the mixed color glass rate to 9% in 1994. In an article in Umwelt (April 1995, pages 150-151), it was noted that only 40 of 540 communities collect mixed glass. In a letter-to-the-editor of Recycling Times on June 27, 1995, Oliver Friedrichs, president of Lune GmbH of Wuppertal, Germany, notes that Germany has effectively avoided the problem of mixed glass since the 1970s by having separate, color-coded igloo-containers for glass. And, although some communities collect green and brown glass in one container, he notes that this practice is discontinuing. Further, he says that many beverages in Germany are sold in standardized bottles which are then returned for reuse.

In Denmark, the goal is also to keep glass source separated by color. Part of this is due to the low value of mixed color cullet. In the Danish Affaldshaandbogen '94/95 (the 1994/95 Solid Waste Handbook) and the February 1995 issue of Ren Viden om Affald og Genanvendelse, the prices paid for the various grades of glass at the glass container manufacturer are listed from 1988 to 1995. Clean clear glass went down from DKr 320 to DKr 240/ton (a 25% decrease), clean colored glass fell from DKr 235 to DKr 120 (a 49% decline), while clean mixed color glass dropped from DKr 170 to DKr 30 per ton (an 82% fall).

Simultaneously with more efforts to keep glass sorted by color at the source, several European firms manufacture equipment to mechanically sort glass by color and to remove contaminants. In the magazine Glass Technology (UK), annotations of articles from a variety of magazines describe systems in operation in Austria, Germany, the Netherlands, and the UK. Other references describe machines manufactured in Italy.

In the September, 1996 issue of Glass Gazette, the main focus of the articles from various European nations was on the necessity of maintaining good quality of the cullet, noting that non-container glass and ceramics are potentially very harmful to the recycling of the cullet.

Further, in the March 11, 1996 issue of Waste News, there is an article describing a developing market for the importation of cullet into Europe from the US, including green glass, mixed-color cullet, and laminated plate glass. It is estimated that in 1996, 100,000 tons of cullet could be shipped to Europe, where the prices paid are much higher than in the US, ranging from \$80 to \$100 for high quality cullet, and \$50 to \$70 for lower quality material. The demand is said to be especially strong in Italy, which has sorting systems that include multiple detectors for ceramics.

UK Waste Resources & Action Programme (WRAP)

The Waste & Resources Action Programme (WRAP) is a not-for-profit company supported by funding from the United Kingdom Department of Environment, Food and Rural Affairs (DEFRA), the UK Department of Trade and Industry (DTI) and the devolved administrations of Scotland, Wales and Northern Ireland. It is working to promote sustainable waste management by creating stable and efficient markets for recycled materials and products.

One of the major focus areas of WRAP is on improving the markets for glass recycling. On its web page, <http://www.wrap.org.uk/>, accessed on July 1, 2003, they include an extensive list of documents that they have produced on the recovery of glass, as follows:

WRAP Publications on Glass Reuse and Recycling July 1, 2003

- Fibre Glass Insulation - the Cold Facts
- Recycled Glass - A Purifying Experience?
- A Clean Look at Glass Reprocessing
- Glass Recycling Made Clear
- Building on Recycled Glass as an Aggregate
- The Art of Glass Recycling
- Recycled Container Glass - the Inside Story
- Recycled Glass Market Study & Standards Review
 - Recycled Glass Market & Standards 1 - Executive summary
 - Recycled Glass Market & Standards 2 - Overview
 - Recycled Glass Market & Standards 3 - Primary Markets
 - Recycled Glass Market & Standards 4 - Alternative markets
 - Recycled Glass Market & Standards 5 - Aggregates
 - Recycled Glass Market & Standards 6 - Filtration
 - Recycled Glass Market & Standards 7 - Abrasives
 - Recycled Glass Market & Standards 8 - Bricks & ceramics
 - Recycled Glass Market & Standards 9 - Niche markets
 - Recycled Glass Market & Standards 10 - Other potential uses
 - Recycled Glass Market & Standards 11 - Reprocessing
 - Recycled Glass Market & Standards 12 - Conclusions
 - Recycled Glass Market & Standards - Appendix 1
 - Recycled Glass Market & Standards - Appendix 2
- Kerbside Collection of Glass
- Recycled Glass - the Abrasive Facts
- Recycled Glass Grit - Information Brochure
- Survey of Waste Glass Collection and Recycling Arrangements in UK Local Authorities
- The Stakeholder Update - Glass
- Research and Development Report - Advanced Filtration Media (AFM) Clean Water Market Analysis
- The Development of a Methodology for Recycling Lamp Glass, Overcoming Technical and Practical Barriers to Recycling
- Recycled Glass Market Study & Standards Review 2003 Update

WRAP is also funding an extensive array of research projects; as of July 1, 2003, eleven projects were listed on their web page of http://www.wrap.org.uk/funded_project_search.asp, as follows:

The ConGlassCrete Project, April 2002 - March 2004

This project aims to effect a significant step-change of mixed colour cullet reprocessing and reuse by the development of added-value end use in appropriate concrete products.

Materials Recovery from Waste Cathode Ray Tubes (CRTs), September 2002 - March 2004

The project will examine all potential markets for CRT (Cathode Ray Tubes) glass, consider the economic and technical barriers to all applications, particularly the higher value applications, and develop the necessary technical standards and processes for commercial take-up.

Market Survey for UK Foam Glass Production to Determine Whether Technology Transfer or Energy Saving Techniques is the Best UK Option, September 2002 - June 2003

Investigation of the economics, whole life costs and best practicable environmental option for introducing a UK foam glass production process by either transferring economically viable technology from other countries or developing energy saving technologies and techniques specifically for UK.

Research on glass derived sands for sports areas, January 2002 - March 2004

The aim of the project would be to determine whether sands derived from recycled glass would give comparable (or better) performance to good quality sands already used in the sports turf industry.

Identifying legal and commercial barriers to glass recycling in West Oxfordshire Interim Reports One and Two, May 2002 - March 2004

To identify the legal and commercial barriers to glass recycling in a representative sample of licensed premises within the geographical region of West Oxfordshire.

To work with waste collection agents, recycling companies, the Environment Agency, glass manufacturers, breweries and business to divert glass from landfill and to promote recycling and where possible re-use of glass.

The commercial bulk production of AFM as a media for water filtration Interim Reports One Two and Three and final report, April 2002 - March 2004

The overall aim of the project is to establish:

- Market acceptance by water authorities/companies for the use of high quality Advanced Filtration Media (AFM) in the treatment of drinking water thus creating a healthy market demand for AFM
- The first full scale production facilities for the production of high quality AFM from processed glass material (PGM), supplied by a network of glass recycling companies, capable of producing 20,000 tonnes of high quality AFM per year.

Determine Vortex Grinder Construction Materials for Glass Cullet Grinding Applications, February 2002 - May 2003

The aim of the project is to investigate the materials of construction for the liner and rotor of the Vortex Grinder so that it can be used for the grinding of glass cullet. This will enable the economic production of fine sized glass which is required for a number of "bulk" and "high-value" applications.

To improve site practices for collection and clean separation of composite materials in the construction and demolition industry, February 2002 - July 2003

The aim of the project is to encourage and facilitate a significant increase in the recycling rates of architectural (flat) glass, especially where composited with steel, aluminum and other materials in frames and other components. This increase will be achieved by improved site practices for collection and clean separation of composite materials, which will also require investment in new plant, and a change in attitude in the industry encouraged by development of a valuable market for the recyclates.

Promoting Best Practicable Options for the Commercially Sustainable Use of Glass Cullet in Construction, March 2002 - March 2004

This project aims to

(a) identify Best Practicable Environmental Options (BPEOs) for the Use of Cullet in Construction, and

(b) promote technical confidence in the material amongst the UK construction industry via an interactive CD ROM and a web-based technical advisory service, providing expert on-line guidance and a source of documents including technical digests, application documents, and case studies.

To demonstrate commercial viability of incorporating ground glass in bricks with reduced emissions and energy savings, April 2002 - March 2004

The aim of the project is to demonstrate that the benefits previously identified in laboratory trials are still available when scaled up to full-scale production. These are principally energy reduction, reduction in stack emissions and maintenance or improvement in quality.

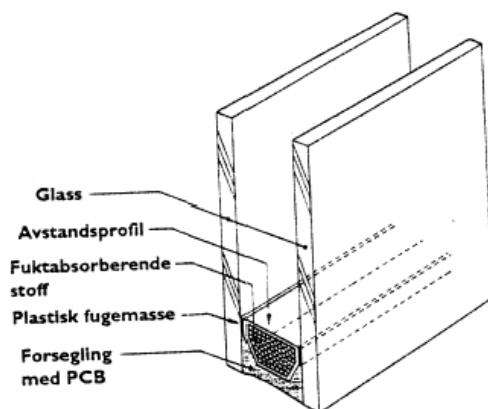
Flat Glass Production and Recycling

According to the US Department of Census publication Current Industrial Reports for flat glass (MQ32A; web site is <http://www.census.gov/ftp/pub/industry>), flat glass production in the US in 1996 was approximately 4.6 million tons, excluding laminated or otherwise fabricated glass. This compares to US container glass production of approximately 9.6 million tons.

While flat glass can generally not be made back into container glass, many of the other recycling techniques highlighted in this database can also be used for recycling flat glass.

In addition, scrap flat glass from window manufacturers can also be made back into flat glass. Recovery of scrap flat glass from old windows -- including those generated during building demolition -- is much more problematic and is generally not done.

One problem associated with the recycling of old windows is the presence of contaminants, including PCBs. According to the Norwegian Pollution Control Agency, insulated glass windows installed in that country from 1965 to about 1980 sometimes included a PCB sealant as shown in the next diagram.



According to several reports, the amount of PCBs contained in each window varies from 50 to 100 grams, and these windows comprise the largest source of PCBs found in Norway in 2001. The agency recommends that workers removing these windows wear personal protection gear and forbids the breakage of these windows except at authorized reprocessing facilities. Several Norwegian building trades associations have established a goal to collect and process all of these windows, rather than allowing them to be disposed in landfills. The associations announced plans to provide for no-charge collection of the windows for reprocessing.

It is not known if such products are found in other countries; attempts by this compiler to obtain information from several US manufacturers were unsuccessful, as the manufacturer did not respond to the inquiries.

Fluorescent Lamp Glass

In recent years, more attention has turned to the recycling of fluorescent lamp glass as an offshoot of the recycling of the mercury from these lamps. The EPA has listed fluorescent lamps under their designation as a Universal Waste, thus facilitating recycling.

In some personal correspondence in February 2000 with Edward Yandek (Edward.Yandek@lighting.ge.com), chair of the Lamp Section Technical Committee of the National Electrical Manufacturers Association (NEMA), data were provided that estimated that approximately 650 million fluorescent lamps are sold each year in the US, composed of approximately 600 million tubes and 50 million compact lamps. For the tubular lamps, approximately 80% are estimated to be 4 feet in length and have approximately 170 grams of glass in the T-8 tubes and 255 grams of glass in the T-12 lamps. (For fluorescent lamps, the 'T' stands for 'tubular', while the number stands for the diameter in eighths of an inch.) Compact fluorescents are estimated to have about 60 grams of glass. Thus, the bulbs sold in the US have approximately 150,000 tons of glass in them.

The composition of the glass varies by manufacturer. Most of the glass in a fluorescent tube belongs to the general family of soda-lime glass, with a typical formula from one manufacturer being:

A Typical Soda-Lime Glass Formula For Fluorescent Lamps

| | |
|--------------------------------|-------|
| Silica oxides | 73.0% |
| Na ₂ O | 16.3% |
| CaO | 4.6% |
| MgO | 3.3% |
| Al ₂ O ₃ | 1.3% |
| K ₂ O | 0.3% |

Source: John Fabisak, Technical Services Manager,
Sylvania, John.Fabisak@sylvania.com, January 24, 2000

However, it should be noted that the part of the end pieces of glass in a fluorescent tube where the electrodes are held can be leaded glass. For compact lamps, the bulb may be entirely soda-lime glass, there may be some leaded glass, or the entire bulb may be leaded glass. The leaded glass may have up to 20-30% lead.

An additional issue with the recycling of the glass from fluorescent lamps is that during the use of the lamp, some of the mercury can be adsorbed by the glass, thus affecting potential end uses for the glass, both in terms of the effects on the glass melting equipment as well as possible emissions. Some uses of recovered glass may also be governed by state or federal land disposal restrictions that set limits for mercury in materials applied to the land (ie, roadway fill).

According to personal correspondence on January 7, 2000 with Paul Abernathy, Executive Director of the Association of Lighting and Mercury Recyclers (abernath@napanet.net), there is between 1 and 3 ppm of mercury in the glass after the glass is processed for recycling and the phosphor powder is removed. The mercury is not detected in the TCLP test, since the mercury is not soluble. According to Mr. Abernathy, in northern California, most of the recycled fluorescent lamp glass is used to make fiberglass insulation. His association does not have information on how fluorescent lamp glass is recycled in other parts of the country.

The data on mercury levels in the glass of fluorescent lamps is also given in a draft NEMA Technical Report from September 1994, "Mercury Content of Residues from Lamp Reclamation". This report lists mercury levels in the glass in F40T12 lamps, with lamp hours ranging from 5,800 to 27,000 hours of use. In general, mercury levels in the glass increased with increased lamp hours, and ranged up to 3.5 milligrams per lamp, which is just under 13 ppm, given that the average amount of glass in such a tube is about 275 grams. The report also showed that the electrodes and lead wires can have up to 179 ppm mercury. The report notes that the TCLP test is not a sufficient test for determining mercury levels in the lamp glass and possible impacts if the glass is further processed, such as

being heated. Additional materials that are in fluorescent lamps that are listed in the report with typical quantities are antimony, barium, chromium, copper, lead, molybdenum and nickel. Ed Yandek pointed out that the average levels of mercury in lamps have come down since the NEMA report first issued, and some lamp types now employ coatings that reduce the amount of mercury that becomes entrained in the glass tubing. However, since not all lamp types employ this coating, it should be understood that currently there is a fairly wide range in the amount of mercury that may be found in the glass from any individual recovered lamp.

NEMA plans to meet with the fluorescent glass recycling industry later in 2000, and discuss subjects related to the recycling of glass from fluorescent lamps.

Cathode Ray Tubes from Computers and Televisions

Although the focus of this report is on glass containers, the recycling of cathode ray tubes is becoming more widespread both due to the increasing quantities of glass from these tubes as well as the recognition that the landfilling of these tubes is a concern due to their designation as hazardous waste.

Approximately 12 -14 million old computers are discarded annually in the US according to a 1997 study published by Carnegie Mellon University with about 80% being desktop computers, the other 20% laptop machines. The exact number of monitors discarded is unknown, but presumably is somewhat equal to the number of computers discarded. The number of monitors to be discarded in the future is likely to grow rapidly. Again, according to the Carnegie Mellon University report, 1996 sales of computers in the US was 25 million, having experienced a 21% growth per year since 1981, and currently, some 130 million computers are said to be in use in the US. While functional monitors can be reused, eventually the monitors either burn out or are of such poor quality that reuse is no longer feasible.

The CRT in a computer monitor is said to weigh an average of 13 pounds. With some 13 million computers being discarded in 1998 in the US, of which 80% are desktops computers, the estimated weight of computer CRTs being disposed of in the US is just under 70,000 tons. The number of television sets discarded has not been found by the author. However, according to information on the webpage of the Television Bureau of Advertising (http://www.tvb.org/researchreports/trends_tv/setsandsales.html), the sale of TV set to dealers was 25 million in 1995 and has been over 20 million since 1984. Thus, some 20-25 million TV sets may be discarded annually. Each CRT in a television can weigh much more than the CRT in a computer, although a more precise calculation would need to incorporate the size of the picture tubes in the TVs discarded. If, for example, a typical TV picture tube weighed four times a computer CRT, the amount of CRT glass from TVs would be an estimated 570,000 tons and the total from computer and TVs would be 640,00 tons.

In comparison, some 9.7 million tons of glass containers are discarded annually in the US.

The Challenge of CRTs

One of the challenges in handling old cathode ray tubes (CRTs) is their hazardous nature because they generally fail the EPA test for toxicity (TCLP test) due to the presence of lead.

CRTs are composed of two glass components along with the electron "gun". The front panel typically makes up 2/3 of the weight of a computer CRT and is lead-free. The funnel and the neck, however, have between 15-20% lead content within the glass, according to several people interviewed as part of this paper and the article "Recycling Special Glass", by Helmut Tietze of Schott Glaswerke, Mainz, Germany, published in Glastech. Ber. Glass Sci. Technol., Vol 68, No. 5, 1995, pages 165-170.

The two glass portions of a CRT are manufactured by separate firms and assembled by a third firm, which adds various coatings and shields along with the electron gun. As part of the assembly process, a frit containing up to 70% lead is used as an adhesive along the edge between the front panel and the side funnel.

Opportunities for Managing CRTs

As a hazardous material, under both federal and state law, CRTs from non-residential sources are not allowed to go to non-hazardous waste landfills, also known as Subtitle D landfills. At this time, however, most generators and landfill owners and operators are unaware of the hazardous nature of CRTs and the need to keep them out of Subtitle D landfills.

In a broad sense, there are two alternatives for properly managing these CRTs -- sending them to a hazardous waste landfill (also known as a Subtitle C landfill) or to get them recycled. This section will focus on recycling opportunities.

Recycling Options for CRTs

There appear to be a fairly limited number of options for recycling CRTs, as follows:

1. Recycle them back into CRTs
2. Recycle into other glass uses
3. Use them for flux in metal refining
4. Miscellaneous applications, such as decorative brick

In general, the electron gun generally needs to be removed from the CRT as part of these recycling opportunities. Usually, the gun is removed by the processor.

There are several market directories for CRTs available on the Internet and these are listed at the end of this section. The author contacted both firms in the Wisconsin area as well as some of the national firms, primarily in the eastern US.

Recycle CRTs Back into CRTs

From a philosophical viewpoint, the optimum situation is to close-loop recycle CRT glass back into CRTs. Due to the differences in chemistry, the CRT would first need to be separated into the panel front and the funnel/neck part, with each part going back to the producer of these components. GWG (Gesellschaft für Wiederverwertung von Gebrauchsgütern) of Bonn, Germany has developed a separation process that they will license. They estimate a cost of \$1.80-\$2.50 per CRT, or \$110 to \$160 a ton, with an average weight of 33 pounds per CRT. It appears from their documents that they are dealing with a combination of TV tubes and computer monitors and arriving at this weight. More information is available on their web page at <http://www.gwg-crt.de> in German, English, Spanish and French.

Experiments were also going on as of the fall of 2001 in England to use the glass from TVs and computer monitors to make glass tiles. The effort is said to be a joint project of Nazeing Glass Works of London and the London regional authority, as well as others.

Envirocycle of Hallstead, Pennsylvania has told me that they use a similar separation process to recycle the CRTs, handling 4 million pounds a month. Envirocycle has been granted a patent (5,236,134) for their process of cleaning the CRT glass prior to recycling. In a telephone conversation in late February 1998, they said that they charge approximately \$6 per monitor, delivered to recycle them this way, lower with larger volumes. They said that the firms that take the CRT glass, (Techneglas of Columbus, Ohio ((614)443-6551) and Corning Asahi of State College, PA((814)231-4200)) recycle it new products.

Corning Asahi confirmed in a phone call on March 9, 1998 that they do recycle CRT glass, both panel glass and funnel and neck glass at their various plants. They would not directly take CRTs from the county, but do take the separated glass from processors, including Envirocycle. Currently, they recycle over 14,000 tons of material a year, including CRT glass.

Techneglas also confirmed in a phone call on March 9, 1998 that they do recycle CRT glass, both the panels and the funnels and necks. They anticipate recycling 20,000 tons of CRT glass this year and have lots of additional capacity. Besides working with Envirocycle, they are interesting in working with other firms, if both their quantity and quality standards are met. For quantity, they would want at least 100 tons of material a month.

Articles in the April 1997 issue of BioCycle and the March 31, 1997 issue of Waste News describe a test project with Conversion Technologies of New Jersey and its subsidiary, Dunkirk International of Dunkirk, New York ((716)366-6600) to determine the economics and markets for dismantling computer monitors and recycling the components. Conversion Technologies is headquartered in Orlando, FL and is primarily in the business of recycling television picture tubes from manufacturers, reselling the glass to the manufacturers. In a phone conversation on March 9, 1998, the company said that the test did not work out well and that they are not pursuing the acceptance and disassembly of whole monitors. However, they do take the CRTs with the electron gun removed, charging \$75 a ton FOB their plant. They said that a typical CRT weighs about 12-14 pounds, although some of the old 14" monitors weigh 16 pounds. They separate the panel from the funnel and neck and market much of the glass to manufacturers. In addition, they have a patent pending on other uses for CRT glass.

One of the limitations on recycling CRTs back into CRTs is that the US discards somewhere on the order of 12 -14 million CRTs a year (along with an yet unknown to me quantity of television sets), but appears to produce less than 2 million new monitors a year (Current Industrial Reports). Thus, the vast majority of CRTs are imported and the capacity does not exist in the US to recycle all CRTs back into CRTs.

Recycle CRTs into Other Glass Types

In phone calls to other firms that said that they recycle CRT glass, a number of other uses for the CRT glass were described, including using to make leaded window glass for skyscrapers, lead-crystal drinking glassware, and glass beads (see, for example, patent number 5,674,616). However, each of these uses has severe limitations. For example, the trade association for flat glass said that leaded glass is never used in window glass. Leaded crystal glass is in disfavor due to the potential to leach lead into the foods. While glass beads made from the panel would not be expected to have a problem vis-à-vis lead, those made from the funnel or neck would be expected to exceed the hazardous waste standard of the TCLP test, given their small size and large surface area, thus facilitating the leaching of lead.

Use CRTs for Flux in Metal Refining

In the refining of metals, one use of a flux is to combine with the contaminants for their removal. A common flux is silica, which is usually provided by sand. Glass can also be used as a flux. When used as a flux in lead smelting, the lead in the CRT can also be recovered.

Phone conversations were had with two firms that are involved in using CRTs as a flux. Steve Burns of ECS Refining of Greensboro ((336)851-1113) said that federal standards only allow CRTs from original equipment manufacturers to be used in primary smelters, while secondary smelters can use post-consumer CRTs. ECS Refining is a primary smelter, but they will process post-consumer CRTs for use by a secondary smelter, primarily in California. Their price is approximately 45 cents a pound for un-housed CRTs and 52 cents a pound for housed CRTs, including transportation from Madison. Large quantities could get a discount of up to 11 cents a pound.

In a phone conversation with Dan Leach ((612)454-3310), of Gopher Resource Corporation, which operates a lead smelter in Eagan, Minnesota. It was learned that they will accept CRTs with all extraneous parts removed for \$9.50 a tube, FOB their plant. The tubes can be shipped in gaylords in truckload quantities. Being a lead smelter, the lead will then be recovered.

Materials Processing Corporation of Eagan, MN also accepts monitors for processing and recycling, using Gopher as the end user. This firm charges \$15 per monitor. Their phone number is (612)681-7362. Rudy Olson, the owner, was unaware of any other local end markets for monitors.

Also, at a May 1997 meeting of the Wisconsin Council on Recycling, a spokesman for United Refining & Smelting said that they will use CRTs in smelting operations and they charge from \$7 to \$10 per monitor. While they formerly used the CRTs themselves, at the time of their presentation, they were shipping them to Noranda. The Doe Run Company of Boss, Missouri also operates a smelter and is said to accept CRTs for use as a flux.

Miscellaneous Applications, such as Decorative Brick

There are probably many other potential applications that are available for recycling CRT glass. In most of the phone calls made to processors, they would either not reveal their markets or would say that the CRTs are shipped to China or the Philippines for recovery, but no specific method of recovery was known to the processor.

One method that is being worked on in Wisconsin by the firm 5R Processors is to break the glass into small pieces, tumble them to remove sharp edges, and then combine them with cement and a coloring agent to make decorative brick. This process builds upon the use of cement as an agent to immobilize lead at hazardous waste disposal sites. However, at the present time, there does not appear to have been any long-term testing of this process, and the impacts of the alkali-silica reaction (ASR) between the cement and the glass. In the construction industry, glass is avoided as an aggregate in concrete because the ASR results in failure of the concrete.

Conversion Technologies, described above as recycling CRT glass back for use as CRTs, also has processes for other uses, including glass beads, which an employee described as an old process. They also have a patent pending on other end uses for CRT glass.

Recyclights in Minnesota ((612)948-0626) recycles fluorescent bulbs and CRTs. Brian Golob said that they charge 65 cents per pound for monitors, CPUs and keyboards. They find that the average monitor with its housing weighs 15-20 pounds, so the charge for monitors is about \$9.75 to \$13, FOB their plant. They would not reveal their market, but said that they take the CRTs to a reputable market "just down the street" from Gopher Resource Corporation at a much lower cost. The 1997 Minnesota market directory did not list any other markets for monitors in this part of the state, however.

In Europe, several projects are reported on the MCC web page listed below for recycling CRTs. The Eureka 1112 project deals with CRT separation, while the FLAIR project deals with CRT recycling techniques. More information is being sought on these projects.

Web sites

The following is a listing of web pages for information on computer and CRT recycling:

<http://www.ce.cmu.edu/GreenDesign/>

A 1997 study from Carnegie Mellon University titled "Disposition and End-of-Life Options for Personal Computers"; an update of a similar study done in 1991.

<http://www.libertynet.org/macredo/eprprj.htm>

A July 1998 study titled End-of-Life Computer and Electronics Recovery. Policy Options for the Mid-Atlantic States, published by the Mid-Atlantic Consortium of Recycling and Economic Development Officials (MACREDO) in conjunction with the Institute for Local Self-Reliance. Includes an excellent list of references, including web sites.

<http://sun1.mpce.stu.mmu.ac.uk/pages/projects/dfe/pubs/dfe16/report16.htm>

A 1994 study by Paul Lambert at the Manchester Metropolitan University on the recycling of CRTs, both exploring alternative approaches and providing detailed data on the composition of CRTs.

<http://www.mcc.com/env>

The environmental site of the Microelectronics and Computer Technology Corporation, with a wealth of information on computer recycling.

<http://www.epa.gov/epaoswer/non-hw/recycle/reuse/electdir/>

An EPA directory of markets for electronics reuse and recycling (530-B-97-001, Electronics Reuse and Recycling Directory). However, many of those contacted did not seem to have specific end markets for the CRTs.

<http://epainotes1.rtpnc.epa.gov:7777/r10/owcm.nsf/recycle/pcrecycle>

A site put together by Region 10 of the US EPA, has good information on local markets for electronics as well as over a dozen links to other sites.

<http://www.nsc.org/ehc/epr2.htm>

This site is put together by the Environmental Health Council of the National Safety Council and includes links to Electronic Product Recovery and Recycling throughout the world

<http://www.epa.gov/commonsense/computer/index.htm>

EPA's Commonsense Initiative, including a section on electronics reuse and recycling.

<http://www.epa.gov/clhtml/pubtitle.html>

A list of EPA publication titles sorted by publication number; these publications can then be read on-line. Included are 530B97001 [Electronics Reuse and Recycling Directory](#), and 310R95002, [Profile of the Electronics and Computer Industry](#).

<http://www.enviroinc.com>

Envirocycle separates the panel from the funnel/neck, and then recycles the glass back to component manufacturers, including Corning and Technoglas.

<http://www.Advancedrecovery.com>

Advanced Recovery of Belleville, NJ has developed a system to recover CRTs. In a phone conversation, they indicated that their charge is \$7 per monitor in quantity, \$12.50 in small amounts. They said that the glass was recycled into skyscraper window glass and other uses and that they would share market information if a letter was faxed to them, but no response has yet been received from a January 29, 1998 request.

<http://eureka.belspo.be/cgi-bin/query35.sh?1112> or <http://www.eureka.be/cgi-bin/query35.sh?1112>

Project (E! 1112): Aquarius. Water Jet Cutting of Cathode Ray Tubes for Clean Recycling is a project to test a method of separating the parts of CRTs to maximize the recyclability of the screen, the cone and the collar, including both the glass, the metal and the chemicals.

<http://www.eureka.be/cgi-bin/query35.sh?1140>

Project E! 1140, Comprehensive Approach To Electronics Recycling: Vision 2000.

<http://www.ihrt.tuwien.ac.at/care/> or (for project list) <http://www.ihrt.tuwien.ac.at/care/projects.htm#top>

Home page of the International Eureka CARE (Comprehensive Approach for the Recycling of Electronics) Vision 2000 office, and includes links to computer and other electronics projects.

<http://www.recycle.net/recycle/Glass/crt/index.html>

This is the CRT page for Recycle Net, which serves as a market place for recyclers. However, there were no listings or background information posted at the time when this site was visited.

<http://www.ibm.com/ibm/environment/crt.html>

Some examples of Swedish art glass objects made from the panels of CRTs.

Miscellaneous Glass Products

The US Bureau of the Census Current Industrial Reports includes a census of consumer, scientific, technical and industrial glassware in report MA32E, available on the Internet at <http://www.census.gov/ftp/pub/industry>.

While this report does not include the weight of these glass products, it does include a count of the number of products manufactured. These glass items are subdivided into the following main and sub categories:

Table, kitchen, art and novelty glassware ~ 1 billion pieces a year

Tumblers
Stemware
Tableware
Cookware

Lighting and electronic glassware Count not given

Automotive lighting
Electric light bulb blanks
Television tube blanks
Lighting bowls, globes and
other glassware

All other glassware Count not given

Generally, non-container glass should not be mixed in with container glass for recycling into containers. However, some of the alternative uses for recycling container glass into non-container uses can also use these types of glass.

Reuse/Recycling Of Glass Cullet For Non-Container Uses

CATEGORY: Building Materials
CLASS: Aggregate

DESCRIPTION: This invention processes glass cullet to both provide roughness to the smooth surface of glass cullet as well as smoothing the sharp edges found on normally crushed glass. First, the cullet is crushed to a mesh size of A32 to B32. The crushed cullet is processed by grinding in a rotating drum that has a grinding agent, water and hydrofluoric acid as an etching agent. There was no description of any testing of this material as aggregate, however.

CONTACT: Patrick Lamoni, Via Cattedrale 14, 6900 Lugano, Switzerland

REFERENCE: Patent 4,997,485, 1991

CATEGORY: Building Materials
CLASS: Counter Tops, Molding

DESCRIPTION: A group of Japanese companies is said to have found a way of turning color contaminated cullet into table tops and building tiles. The process involves crushing waste glass to a powder and then mixing it with a special adhesive-containing cement.

CONTACT: Unknown

REFERENCE: Glass, March 1993, page 118

CATEGORY: Building Materials
CLASS: Counter Tops, Molding

DESCRIPTION: A Montana firm is making counter tops by combining glass cullet with power plant fly ash. As of the fall of 2002, the material was selling for \$80 a square foot.

CONTACT: Headwaters Composites Inc., Three Forks, Montana

REFERENCE: "Glass", Resource Recycling, October 2002, page 37

CATEGORY: Building Materials
CLASS: Counter Tops, Molding

DESCRIPTION: A non-porous blend of epoxy, recycled glass and fillers is used to make counter tops and molding in either matte or gloss finish. It uses 30-60% post-consumer glass.

CONTACT: Decorative Stone Concepts, 8849 NE 137th Place, Kirkland, WA 90034 (206)821-4819

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: Doors

DESCRIPTION: Flat and designer glass for doors, windows, walls, shower doors, tables and dividers can be made with up to 10% post-consumer glass.

CONTACT: UltraGlas, Inc., 9186 Independence Avenue, Chatsworth, CA, (818)772-7744

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: General

DESCRIPTION: In Thurston County, Washington, two entrepreneurs have developed a concrete using mixed color glass as the aggregate. The concrete was used to build bird houses, but later discontinued because it was so labor intensive. Instead, they turned their attention to building paving squares with a smooth, glazed surface, along with garden landscaping bricks, home planters, table tops and candle holders. At the time the article was written, the firm had 50 molds and produced about 300 pieces a month.

CONTACT: Scatter Creek Enterprises, Rochester, WA

REFERENCE: "Colored Cullet makes Products Sparkle", Mary E. Harrington, BioCycle, September 1998, pages 68-69

--CATEGORY: Building Materials
CLASS: General

DESCRIPTION: In the late 1940's, Harry Bailey of Lebanon, Tennessee built a single family home with glass bottles as part of the home's perimeter walls. The bottles, which are still intact, are embedded for their artistic value. The home is now owned by a nephew, Craig Pitts.

CONTACT: Craig and Nodia Pitts, Lebanon, TN

REFERENCE: "They Do Not Throw Stones", Byron Acohido, Waste News, August 17, 1998, page 12

---CATEGORY: Building Materials
CLASS: General

DESCRIPTION: As an alternative to the traditional processes of making foam glass using a foaming agents, this research was aimed at using mica as both a part of the product matrix as well as a foaming agent. The glass containers were pulverized into fine grains of between 0.2 and 0.5 mm diameter, then ground into fine powder (150-300 micrometers) by a dry ball-milling operation for five hours, combined with varying percentages of mica, and then heated to a range of temperatures. It was found that at low percentages of mica, open and closed cells were formed within the structure, producing a light weight, but relatively weak (0.877 MN m⁻²), material, while at higher levels of mica, the cells were no longer formed and the material was very strong (53 MN m⁻²). Both materials had a good insulating value. It was further found that the amount of compaction pressure used in the formation of the composites before sintering had little effect on the final density of these two forms of the product. In contrast, the sintering temperature had a major impact on both density and the apparent porosity, with the cellular material having the highest density at 850 degrees C and the dense material having the lowest density at the same temperature. It was noted for both structures that the compressive strength increased with density. Changing the amount of water added during the mixing process had little impact on the density of the dense structured material, but a significant impact on the density of the cellular material, with the greatest density at an added water amount of 4 ml per 50 grams of glass and mica (90% glass and 10% mica). Changing the

amount of water added did not, however, have much impact on the compressive strength. Finally, there did not appear to be any correlation between the thermal conductivity of the glass-mica composites and the three factors of compression during forming, sintering temperature or amount of water added.

CONTACT: unknown

REFERENCE: "Fabrication of Cellular Structure Composite Material from Recycled Soda- Lime Glass and Phlogopite Mica Powders", Norman M. P. Low, Journal of Materials Science, vol 15 (1980), pp 1509-1517, and "The Effects of Temperature, Pressure and Water on the Preparation of Glass-Mica Composite Material", Norman M. P. Low, Journal of Material Science, vol 15 (1980), pp 2497-2507

CATEGORY: Building Materials

CLASS: General

DESCRIPTION: These two articles are in followup to the research reported above. Foam glass was developed using both calcium carbonate and sodium carbonate and using mica with recycled colorless glass cullet. The cullet was first ground to about 0.2 to 0.5 mm, and then further ground to 150-300 micro-meters. The calcium carbonate was 200 mesh, the sodium carbonate was 100 mesh, and the mica was less than 300 micrometers in size. The mixtures were sintered at temperatures above 850 degrees C. It was found that the calcium carbonate mixture had the highest expansion, and the greatest thermal resistance, while the mica mixture had the least expansion, and compared to the calcium carbonate mixture, about double the thermal conductivity and five times the strength. The sodium carbonate mixture had nearly the same expansion as the mica mixture, slightly worse thermal insulation, and only about one-fourth the compressive strength. The researchers later determined that the main cause of the expansion of the mica mixture was from the water of crystallization of the mica; if the mica was heated to about 1050 degrees C before mixing with the glass, there was little expansion.

CONTACT: unknown

REFERENCE: "Formation of Cellular-structure Glass with Carbonate Compounds and Natural Mica Powders", Norman M. P. Low, Journal of Materials Science, vol 16 (1981), pp 800-808 and "The Effect of Mica Dehydration on the Fabrication of Cellular Glass-mica Composite Solids", Norman M. P. Low, Journal of Materials Science, vol 17 (1982), pp 1585-1590

CATEGORY: Building Materials

CLASS: General

DESCRIPTION: The Sunlight Company of Japan, a joint venture that includes Kirin Brewery Company and Showa Glass Company, has developed technology to transform post-consumer glass bottles into construction materials, such as sound absorption material, insulation and tiles. The glass is pulverized and bake to produce grains that are 0.3-0.5 mm and then mixed with cement or clay to make the products. A \$18 million demonstration plant has been built in Ibaragi Prefecture.

CONTACT: Unknown

REFERENCE: Resource Recycling's Bottle/Can Recycling Update, February 1995, page 5

CATEGORY: Building Materials
CLASS: General

DESCRIPTION: The Ovambo tribe of Namibia is using glass bottles instead of wood to build their houses, laying the bottles on their side and covering them with cement.

CONTACT: Unknown

REFERENCE: All About Recycling, newsletter of the Pennsylvania Resources Center Summer 1995, page 7

CATEGORY: Building Materials
CLASS: General

DESCRIPTION: Wil-Manufacturing Inc of Canada has begun a process to recycle scrap glass from fiber glass to be used to strengthen composites of plastic and rubber, and as a component of building products.

CONTACT: Wil-Manufacturing, Guelph, Canada

REFERENCE: Industrial Sand and Gravel. Annual Review - 1994, US Department of the Interior, Bureau of Mines, September 1995, page 2; also see "Plant Opens for Glass Fiber Recovery, Ceramic Industry, November 1994, page 15

CATEGORY: Building Materials
CLASS: Glass Brick

DESCRIPTION: Hot Stuff Glass Works has received a \$10,000 state grant to develop glass bricks for use in paving, concrete work and decorative edging. The bricks are to be stamped in a mold and then can be polished, etched or sandblasted. The firm also makes glass tiles from recycled glass.

CONTACT: Bill Sargent, Hot Stuff Glass Works, Bellingham, Washington

REFERENCE: BioCycle, May 1994, page 25

CATEGORY: Building Material
CLASS: Glass Brick

DESCRIPTION: The glass industry trade association in the UK, British Glass, looked at a variety of opportunities to recycle glass cullet, including glass bricks. Trials were set up to test the effects of up to 10% addition of finely ground glass powder [to act as a flux] to the five most commonly used brick clays in the UK. The results indicated that the addition of powdered glass can provide comparable strength to the bricks as if the temperature were 50°C higher, thus providing a significant fuel savings.

It would also be possible to add cullet as a filler, but the economics do not appear to be favorable, as the cullet would then be replacing clay that costs £1/tonne. However, some clays have fluorine, giving rise to air pollution control problems, which the use of glass cullet would assist.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256- 258

CATEGORY: Building Materials
CLASS: Glass Brick

DESCRIPTION: Whatcom County, Washington is working with a local art glass studio to secure a grant for testing a recycled glass brick prototype. McDonald's used the recycled glass brick in a new store.

CONTACT: Whatcom County, Washington

REFERENCE: The NRC Connection, November/December 1993, page 9

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Aurora Glass Foundry of Eugene, Oregon produces a variety of architectural and decorative glassware – including glass tile -- using 100% recycled glass. It is part of Saint Vincent de Paul's recycling program.

CONTACT: Aurora Glass, (888) 291-9311

REFERENCE: Internet web pages, <http://www.auroraglass.org/>,
<http://www.svdplanecounty.org/mainsite/recycling/aurora.html>, accessed July 1, 2003

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CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Quarry Tile Company in Spokane, Washington, manufacturers Eco-Tile, using roughly 70% recycled content, including recycled glass, grinding paste from the computer industry and recycled soil and rock waste from the sand and gravel industry. Eco-Tile is available in more than 50 colors and five sizes.

CONTACT: Quarry Tile Company, Spokane, WA, (800)536-2812, or <http://www.quarrytile.com>

REFERENCE: "Quarry Tile Co. Joins LinkUp", Recycling Today, March 2003, page 12

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: A pilot plant is being established by Elizabeth City Glass to produce fused-glass products, including floor and wall tiles, sandblasting abrasives, pavers, concrete aggregate, drainage pipe and filter media.

CONTACT: Shawn Lemmond, Elizabeth City Glass, North Carolina

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

--- CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Sandhill Industries of Boise, Idaho has received an award from the US EPA for their process of using post-industrial recycled glass to make outdoor decorative glass tile. The process uses only 750 BTUs to make a pound of tile, versus 1,800 BTUs for the production of a traditional

ceramic tile. The process is also said not to result in any emissions of CO₂. In the last year, the company has used 50,000 pounds of recycled glass.

CONTACT: Sandhill Industries, Boise, Idaho, web page <http://www.sandhillind.com/>, accessed December 12, 2002

REFERENCE: "EPA Awards Glass Recycling Process", Recycling Today, November 2002, page 17, and Internet web page <http://www.ci.boise.id.us/pds/newsletters/Fall-2002.pdf>, accessed December 12, 2002

--- CATEGORY: Building Materials

CLASS: Glass Tile

DESCRIPTION: Bedrock Industries of Seattle, WA makes glass tile, dinnerware and other specialty items, having used more than 50 tons of recycled glass in 2001, and 100 tons in 2002. They have joined the King County, WA LinkUp program, and will be testing the glass tile for performance factors, such as thermal shock, water absorption, friction, abrasion and strength. The company was started in 1993 by glass artist Maria Ruano.

CONTACT: Bedrock Industries, Seattle, WA

REFERENCE: "Glass Tile Maker Joins King County Program", Recycling Today, September 2002, page 9, "Seattle, Washington. Valentine's Day on Puget Sound Features Recycled Glass Hearts" BioCycle, February 2003, page 16

--- CATEGORY: Building Materials

CLASS: Glass Tile

DESCRIPTION: Heritage Glass of Smithfield, Utah is making a terrazzo glass tile of recycled glass. The material has been used in the Denver and San Francisco airports, among other places.

CONTACT: Heritage Glass, Smithfield, Utah

REFERENCE: "Glass", Resource Recycling, October 2001, page 36

--- CATEGORY: Building Materials

CLASS: Glass Tile

DESCRIPTION: Wausau Tile in Wausau, Wisconsin is making a terrazzo glass tile with recycled glass.

CONTACT: web page <http://www.wausautile.com>, Wausau Tile, 9001 Business Hwy 51, PO Box 1520, Wausau, WI 54402-1520, (715)359-3121

REFERENCE: Company literature and "Glass", Resource Recycling, October 2001, page 36

--- CATEGORY: Building Materials

CLASS: Glass Tile

DESCRIPTION: A new firm known as Ice Stone is being established in New York City to produce a terrazzo-like tile made with crushed recycled glass and added to a cement-based mixture. The tiles will include panel-sized products and will be produced in a 65,000 square foot facility in the Brooklyn Navy Yard.

CONTACT: Tim McCarthy, Ice Stone, New York, New York

REFERENCE: "New York. New York. New Firm Recycles Glass into Tile", BioCycle, August 2001, page 18

--- CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Environmentally Correct Projects, Inc. (ECP) of Vero Beach, FL has announced their intention of building a \$10 million plant to recycle mixed glass cullet into glass tile in Wood River, IL (just east of St. Louis, MO). The plant will be a joint venture between ECP and Futuristic Tile LLC of Allenton, WI, with ECP having a 90% ownership. The owners expect to make 5 million floor tiles a year from 23,000 tons of mixed glass, with a possible production of 20 million tiles a year after 5 years. As of November 1998, construction was underway.

CONTACT: Environmentally Correct Projects, Vero Beach, FL (has a web page); Tim Grahl, Futuristic Tile, (800)558-780, also see web page on http://www.grn.com/home/fut_tile/index.html

REFERENCE: Waste News, June 22, 1998, page 21; "Alternative Uses for Cullet Found", Glass Industry, August 1998, page 7; Resource Recycling, November 1998, page 40

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Lake County, IN is offering Futuristic Tile financial support to develop a facility to recycle glass into imitation ceramic, marble and granite tiles. The County is considering floating an \$8 million bond to assist the firm, which the firm would repay in 5 years. In the firm's process, glass is ground to a powder, heated to near liquid, placed in molds and then heated in electric kilns. The cost of the tile is estimated at \$1 a square foot, versus tile of the marble and granite at \$50 a square foot. The County initiated the offer to Futuristic Tile after obtaining information about the firm's process at a recycling conference.

CONTACT: Bruce Lindsey, Chief Executive Officer, Futuristic Tile, PO Box 388, Allenton, WI 53002, (414)629-5521

REFERENCE: "Glass Plant Seeks Bond", Waste News, November 11, 1996, page 16

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Futuristic Tile (listed as Allentown, PA, but more likely Allenton, WI) says it can make ceramic tile from scrap bottle cullet for about 97 cents per square foot, which provides an 18% profit. The average price of domestic tile is about \$1.23 a square foot. A \$6.5-\$7.0 million facility could make about 4 million square feet of recycled tile annually, and use about 10,000 tons of cullet a year.

CONTACT: Jim Walters, President, Futuristic Tile

REFERENCE: Resource Recycling, July 1996, page 129

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Futuristic Tile of Allenton, WI has received funding from the Wisconsin Recycling Market Development Board for developing a facility to make glass tile from cullet. The technology is said to have been developed by former Russian defense scientists under the name of Crystal Growth Equipment, headquartered in Prague, Czech Republic. The application says that the US

ceramic tile industry has over \$1.2 billion in annual sales, and that the industry has 20 firms that control 95% of the market. However, none of these firms have expressed interest in using this technology. Futurist Tile plans to demonstrate its system, and then license the technology to others and achieve a 5% market penetration (\$30 million in annual sales) within 5 years, having 18 production facilities by 2000.

The tile is said to have the appearance of natural stone, and that there is high distributor and consumer interest, especially in "green" locales, such as Germany.

CONTACT: Bruce Lindsey, Chief Executive Officer, Futuristic Tile, PO Box 388, Allenton, WI 53002, (414)629-5521

REFERENCE: Financial assistance proposal summary prepared by the Wisconsin Recycling Market Development Board, March 27, 1996; personal conversation with RMDB staff, May 24, 1996

--- CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: A Wisconsin firm received state funding to demonstrate the manufacture of a variety of materials from glass cullet, including glass tile. The tiles were found to be superior to ceramic tiles, having greater strength, better bonding power, and being impervious to water. Two hundred glass tiles were installed in a Plymouth grade school in 1991. A June, 1993 notice described the commercial sale and production of the tiles, which can be customized with various designs or motifs. In April 1996, the company received an early planning grant from the Wisconsin Recycling Market Development Board to further investigate the production of glass tile with glass cullet.

CONTACT: Ray Selk, Chicago Art Glass and Jewels, Inc., 937 Pilgrim Road, Plymouth, WI 53073, (920)892-2744

REFERENCE: Grant proposal of Chicago Art Glass to the Wisconsin Department of Natural Resources; final project report to DNR, 1992; Wisconsin Procurement News, June 1993, page 2; telephone conversation with Gail Miller Wray, executive director of the Wisconsin Recycling Market Development Board, April 16, 1996

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: A recycling cooperative in southeast Minnesota has received a grant from the state of Minnesota to research the manufacture of glass tiles, blasting medium and beads for reflective surfaces from recycled glass by their local industries. The project will last for two years (c. 1997).

As of April 1996, the cooperative had purchased a glass crusher and had modified it to produce the particle size that was needed, and had test made glass bricks. They were both negotiating with Futuristic Tile to license their system as well as looking at moving ahead with the technology that they themselves had developed.

CONTACT: Ann Nelson, WORC Industries, (507)452-1855; Susan Waughtal, SEMREX, 856 5th Avenue, Rochester, MN 55904, (507)252-0750

REFERENCE: Personal conversation with staff of the Minnesota Recycling Market Development Program, April 28, 1995; telephone conversation with Susan Waughtal, April 15, 1996

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Futuristic Tile of Allenton, WI has acquired the rights of a glass tile manufacturing process from Czechoslovakia, and will be marketing the technology and equipment in the US. The process can use any type and mixture of glass if the various types of glass melt within 5 degrees of each other. The tiles were shown at several conferences and received good feedback.

CONTACT: Jim Walters or Bruce Lindsey, Futuristic Tile, PO Box 388, Allenton, WI 53002, (800)558-7800

REFERENCE: Personal phone conversation with Jim Walters, January 9, 1996

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: The 1996 Glass Industry Directory lists the following firms as manufacturers of glass tile (it was not stated if the firms use cullet to manufacture the tile):

Floral Glass & Mirror, Inc.
895 Motor Parkway
Hauppauge, NY 11788
(516)234-2220

Gillinder Brothers, Inc.
Box 1007
Erie & Liberty Streets
Port Jervis, NY 12771
(914)856-5375

Hills Glass Ltd.
Nechells Park Road
Nechells, Birmingham B7 5NQ ENGLAND
(021) 328-7711

Paisa Fund Glass Works
Talegaon Dabhade (C. Rly)
Dist. Pune 410507 INDIA
02114-22329

Pilkington (Australia) Ltd.
PO Box 7388
Melbourne, Victoria 30004 AUSTRALIA
03-525-5666

Saint-Gobain Exprover S.A.
Avenue de Tervuren 300
Boite No. 4
1150 Brussels, BELGIUM
778.99.50

L. E. Smith Glass Co.
PO Box 963
Mt. Pleasant, PA 15666
(412)547-2077

Sylvania & Laxman Ltd
68/2, Najafgarh Road

New Delhi 110015 INDIA

T. & W. Ide Ltd.
Glasshouse Fields
London E1 9JA ENGLAND
0171-790-2333

TSL Group PLC
PO Box 6, Neptune Road
Wallsend
Tyne and Wear, NE 28 6DG ENGLAND
091-262-5311

Vidrotil Industria e Comercio Ltda.
Rua Loefgren, 1496
Sao Paulo, BRAZIL 04040
(011) 5499714

Waterstone Glassware Ltd.
Common Lane, Wath-upon-Deame
Totterham, South Yorkshire S63 7DY ENGLAND
01709 878721

Wiesenthalhutte GmbH
Postfach 11
Perlenweg 5
7325 Schwaebisch, Gmund GERMANY
07171-108-0

In the descriptions of the products of the these firms, only the listing for Vidrotil Industria e Comercio Ltda. included glass tiles as a product manufactured by the firm.

CONTACT: Individual firms

REFERENCE: 1996 Glass Industry Directory Issue, volume 77, number 3

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: An Indiana firm makes high endurance glass tiles sold under the trade name of Craftsman from cullet ground and refined to the consistency of powdered sugar. The tiles have a recycled content of 60-70%, of which about 80% is post-industrial scrap, mainly mirror and aircraft glass, with the remainder being post-consumer clear cullet. The tiles sell for a premium price over ceramic tiles and are said to be stronger, denser, more stain resistant and less muddy in color. The company was founded in 1987, has 20 employees and about 0.2% of the national tile market. The firm is said to be uninterested in licensing their process to others.

Major users have included McDonald's, Burger King, Disney, and the US Army.

In early 1995, this firm was purchased by John Golitz, president of Terra-Green Technologies, Inc., Arlington Heights, IL. As of spring 1995, they offered glazed tile in 14 colors, six sizes and three trim styles.

Stoneware Tile is described in a 1996 publication as "The world's only producer of ceramic tile from post-consumer glass." The article goes on to say that the tile is well-received by architects

and designers, and it is featured in several high-profile buildings, including Team Disney's new office complex near Orlando, FL. Feedstock includes plate glass, windshield glass, industrial scarp cullet and quarried clay. The firm produces 56 tons per day of 70% recycled-content tile. The Ceramic Tile Institute has awarded Stoneware Tile its Diamond Award for Superior Quality.

CONTACT: Kenneth Cloud, Vice-President Sales and Marketing, or Richard Moore, Vice President and General Manager, Stoneware Tile Company, Richmond, IN, (317)935-4760; Terra-Green Technologies, (708)228-1800.

REFERENCE: "Creating Local Jobs from Environmental Protection. Focus on Recycling and Small Business", March 1992, T. Paul Robbins, et. al., (city, organization unknown; received from Erv Sandlin, Texas Water Commission), Resource Recycling's Bottle Can Recycling Update, July 1992, page 4, Resource Recycling, June 1993, pages 101-102, Recycled Products Business Letter, August 1993, page 3; Resource Recycling's Bottle/Can Recycling Update, February 1995, page 5; Resource Recycling, May 1995, page 15; "Critical Links in the Recycling Chain", Views on Responsible Environmental Management, WMX, Winter 1996, pages 8-9, "Indiana Co. Finds Niche in Recycled Tile", Ben Hughes, Recycling Times, September 1, 1998, page 10

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Sun Valley, Idaho and Western Mobile (Boulder, CO) are using crushed wine bottles to make tile.

CONTACT: Unknown

REFERENCE: "Southwestern Recyclers Learn the Latest at Annual Conference", Recycling Times, c. November 1995, pages 10, 12

CATEGORY: Miscellaneous
CLASS: Glass Tile

DESCRIPTION: This is a research project designed to develop a process for fabricating architectural glass tiles from recyclable cullet, following two primary goals: (1) to use mixed-color cullet, and (2) to use a sintering process of about 750°C, rather than a melting process of some 1400°C. [A sintering process fuses particles together at a temperature below the melting point.]

A market survey found no companies making sintered glass tiles; instead glass tiles were made by melting the glass, while ceramic tiles were made by the sintering process.

Three processes were tested to form the tiles prior to sintering -- tape casting, thixotropic casting, and slip casting. Tape casting did not work both because the formulations were too fluid, and because of difficulties in removing the cast tape from the casting plate. Thixotropic casting also failed, due to the a large number of voids in the material and wavy edges in the tiles. Slip casting also had significant problems, but successful castings were made by using HDPP molds with corn oil as a mold release, and with a trimodal distribution of particle sizes, fired with plaster of Paris sprinkled on top of the green molded tiles.

Two main processes were tested for coloring the tiles. As noted in an earlier study, bulk coloring was deemed as not workable, and so the focus was on surface coloring. In the first process, "China paint" was used both after the tile had been fired, and alternatively, applied to the green molded tile. Unfortunately, neither process worked well. The second process studied was the use of a surface coat of clear (flint) glass with coloring agents, which had been melted

and reground. While color coatings could be successfully applied, there were problems with the uniformity of the coating and achieving a glazing. The researchers also suggested that polymeric paints be studied as a possible coating.

In a preliminary economic analysis, it was found that a system to produce 10,000 glass tiles a day would use 1.5 tons of glass daily, require a capital investment of \$300,000 and produce an annual profit of \$65,000.

For future research, it was recommended to find ways to improve the coloring of the tile, to find less expensive binders, and to determine the physical properties of the tiles.

CONTACT: Dr. Guna Selvaduray, San Jose State University, (408)924-3874

REFERENCE: Recycled Glass: Process Development for Sintered Architectural Glass Tiles. Final Report, Dr. Guna Selvaduray, Materials Engineering Department, San Jose State University for the City of San Jose, June 28, 1995, 56 pages

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: The University of Washington Ceramics Engineering Department is investigation ways to optimize the manufacture of permanent molds from castable refractory materials. The expected completion date is June 1995, and a video on the process is to be available at that time as well.

CONTACT: University of Washington Ceramics Engineering Department

REFERENCE: Personal correspondence from Bob Kirby, CWC, March 6, 1995, (206)443-7746, email kirbgood@aol.com

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: In May, 1995, a survey was sent to ceramic tile manufacturers listed in the Thomas Register, asking firms that use glass cullet to send us information on their products. As of June 19, 1995, two firms have responded, but neither uses glass cullet, although Heath Ceramics of Sausalito, CA says that they have used glass cullet in the past and could use it in the future, since some of the chemicals needed to make certain types of tile are in short supply.

CONTACT: John Reindl, Dane County Recycling Manager, 1919 Alliant Energy Center Way, Madison, WI 53713, (608)267-8815

REFERENCE: Personal survey, spring 1995

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: TERRA-GREEN Technologies manufacturers tiles made of more than 55% glass cullet. The tiles are said to be suitable for residential and light commercial application in floors, walls and counter tops.

CONTACT: TERRA-GREEN, Technologies, Millersville, MD

REFERENCE: Recycling Times, May 2, 1995, page 11

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: The New Jersey Department of Environmental Protection is talking with the Rutgers School of Ceramic Engineering about doing a research project to investigate the use of cullet to make ceramics. This would be a high value end use of cullet.

CONTACT: New Jersey Department of Environmental Protection

REFERENCE: Resource Recycling's Bottle/Can Update, February 1995, page 5

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: The California Integrated Waste Management Board has provided funding to Oceanside Glasstile Company of North San Diego County [presumably for the company to make glass tile from glass cullet].

CONTACT: California Integrated Waste Management Board

REFERENCE: Resource Recycling, February 1995, page 8

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: San Jose State University looked at potential products to make out of recyclable glass, looking at products that would be high value, use a large volume of material, and be able to handle mixed color cullet. Three products were identified that could meet these criteria: sintered glass tile, water/wastewater filters, and glass polymer composite pipe.

For the glass tiles, the study looked at three initial sizes of material: fines, 12 mesh, and 5/8" particles, looking at moisture content, organic and combustibles content, and for the fine and 12 mesh material, particle size distribution. Glass of -40 to -60 mesh was then combined with a binder to make pellets, which were then sintered (heated, but not melted) to form tile. This process tested was found to be technically feasible, but the economics did not appear favorable, and it was difficult to color the tiles -- bulk coloring did not work due to the mixture of colors in the glass. Therefore, alternative forming methods were tested, along with other coloring techniques. Further tests were recommended, with a more intense study begun as a second phase, to be finished in 1995.

CONTACT: Dr. Guna Selvaduray, San Jose State University, (408)924-3874

REFERENCE: Recycled Glass: Development of Market Potential. Final Report, Dr. Guna Selvaduray, Materials Engineering Department, San Jose State University for the City of San Jose, July 14, 1994, 45 pages

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Firm makes 3-3/4" square tile and architectural shapes of recycled post-consumer and post-industrial glass.

CONTACT: Bedrock Industries, 3410 Woodland Park Ave N, Seattle, WA 98103, (206)781-7025

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Firm makes ceramic-like unglazed tile, and simulated marble and granite molded stone with post-consumer glass and other products.

CONTACT: Pacific Strategies, 1101 Connecticut Ave., NW, #1000, Washington, DC, (202)828-2320

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: GTE/Sylvania makes high endurance glass tiles from light bulb cullet from its bulb manufacturing operations. The company does not believe that they could use post consumer cullet because of their need for high optical and density quality.

The 1994 Harris Directory reports that this firm was sold to a German company, but that the tiles are still available.

CONTACT: Frank Pellegrino, GTE/Sylvania, location unknown; also GTE Products Corp., 1 Jackson Street, Wellsboro, PA 16901, (717)724-8200

REFERENCE: "Creating Local Jobs from Environmental Protection. Focus on Recycling and Small Business", March 1992, T. Paul Robbins, et. al., (city, organization unknown; received from Erv Sandlin, Texas Water Commission); The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: In Australia, Glass Phoenix Pty. Ltd is making a marble and granite substitute from recycled glass for glass tile, walls, and table tops.

CONTACT: Glass Phoenix Pty. Ltd, Queensland, Australia

REFERENCE: Resource Recycling, February, 1994, page 70

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Hot Stuff Glass Works in Bellingham, Washington makes glass tiles from recycled glass. Recently, they've also started making glass bricks from recycled glass.

CONTACT: Bill Sargent, Hot Stuff Glass Works, Bellingham, Washington

REFERENCE: BioCycle, May 1994, page 25

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: The glass industry trade association in the UK, British Glass, looked at a variety of opportunities to recycle glass cullet, including glass tiles and castings. For roofing tiles, a low porosity value is needed, and the glass can be used as a flux to reduce porosity. Floor tiles, on the other hand, have different requirements, but glass can also be used there, and can be used to create decorative effects. For an effect similar to terrazzo, tiles and in-situ casting for complete floors are all easily produced and said to be cheaper than marble, which is the basis for terrazzo.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256-258

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: A group of Japanese companies is said to have found a way of turning color contaminated cullet into table tops and building tiles. The process involves crushing waste glass to a powder and then mixing it with a special adhesive-containing cement.

CONTACT: Unknown

REFERENCE: Glass, March 1993, page 118

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Research was done to determine the effect of a variety of variables on green strength, physical properties of the fired product and the microstructure and vitrification of ceramic-like products made from recyclable glass and clay. Variables studied included: (1) the size of glass particles, (2) the type of clay binder, (3) the amount of clay binder, (4) the amount of water used to mix binder and glass, (5) the pressing pressure used to form the product, (6) the use of drying before firing, (7) the heating and cooling rate for firing the product, (8) the soaking (firing) temperature, and (9) the soaking (firing) time. For the green strength, it was found that the most beneficial improvements could be made by optimizing the amount of water used to mixed the materials and by drying the green product. Also helpful was going to a smaller size of glass particles and using more clay, but these improvements in green strength also had a negative impact on the physical properties of the finished product. For the firing process, the most important variables appeared to be soaking temperature ((940 degrees C optimal) and soaking time (at least 30 minutes). Other variables that had a noticeable impact included: use a big particle size for the glass, use as small as possible quantity of binder, the water used in mixing should be 4% (for mixtures with 10% binder), and use high pressing pressures. The research found that glass tiles produced by the process described in these papers was as strong as or stronger than commercial ceramic tiles, even without optimizing the process. Because the optimal firing temperatures were lower than for traditional ceramic objects, the authors concluded that this process is more energy efficient than traditional ceramic processes.

CONTACT: unknown

REFERENCE: "Process Design for the Production of a Ceramic-like Body from Recycled Waste Glass", I. W. M. Brown, K. J. D. Mackenzie, Journal of Material Science, 1982, pages 2164-2193 (Part 1. The Effect of Fabrication Variables on Green Strength, pages 2164-2170. Part 2. The Effect of Fabrication Variables on the Physical Properties of the Fired Body, pages 2171-2183. Part 3. The Influence of Microstructure and Devitrification Behaviour on the Physical Properties, pages 2184-2193.)

--CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Prior to 1982, recovered glass from incinerator residue was used to make glass tile used for the foyer in a building in Florida.

CONTACT: unknown

REFERENCE: "Process Design for the Production of a Ceramic-like Body from Recycled Waste Glass", I. W. M. Brown, K. J. D. Mackenzie, Journal of Material Science, 1982, page 2164

--- CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: A process developed at UCLA to make ceramic tile out of waste bricks and sewage sludge may also be capable of using glass cullet.

CONTACT: unknown

REFERENCE: Glass Recycling and Reuse, Harold R. Samtur, University of Wisconsin-Madison Institute for Environmental Studies Report 17, March 1974, 100 pages; "Recycling Container Glass. An Overview", John H. Abrahams, Jr., Third Mineral Waste Utilization Symposium, March 14-16, 1972, pages 144-150. Also see "Broken Glass Plus Manure Makes Cheap Bricks", Industrial Research, September 1971 and "Sewage Sludge, Bottles Combined to Make Tiles", Chemical Engineering, November 15, 1971, page 96

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Prior to 1972, the US Bureau of Mines Ceramic Laboratory was developing vitreous and mosaic tiles using glass from incinerator residue. The typical mixture is 50% glass and 50% clay. When fired to 1830 °F, the tiles have a water absorption of only about 2%.

CONTACT: unknown

REFERENCE: "Recycling Container Glass. An Overview", John H. Abrahams, Jr., Third Mineral Waste Utilization Symposium, March 14-16, 1972, pages 144-150

CATEGORY: Building Materials
CLASS: Glass Tile

DESCRIPTION: Prior to 1972, a researcher in Florida, Mr. D. Thomas, was making tile out of 50% scrap glass and a clay mineral plasticizer and a mineral filler. Heated to a temperature of 2000 °F, the tile has a water absorption of nearly zero.

CONTACT: unknown

REFERENCE: "Recycling Container Glass. An Overview", John H. Abrahams, Jr., Third Mineral Waste Utilization Symposium, March 14-16, 1972, pages 144-150

CATEGORY: Building Materials
CLASS: Masonry Coating

DESCRIPTION: A Seattle, WA firm has developed a masonry coating made with recovered glass as a substitute for the sand.

CONTACT: Eco Coatings, Seattle, WA

REFERENCE: Resource Recycling, March 1996, page 58

CATEGORY: Building Materials
CLASS: Masonry Coating

DESCRIPTION: In Scottsdale, AZ, the city is working with a private firm (Enviro Sand, Inc.) to grind glass bottles into six different sizes, including marble size pieces for landscaping as well as art objects, sand for use in stucco, ashtrays and construction projects, and chalk for painting lines on baseball fields.

CONTACT: Dennis Enriquez, City of Scottsdale environmental coordinator, Dave Columb, President, Enviro Sand Inc.

REFERENCE: "Glass Breads Into Pebbles in Ariz.", Bruce Geiselman, Waste News, June 8, 1998, page 17; "Alternative Uses for Cullet Found", Glass Industry, August 1998, page 7

---CATEGORY: Building Materials
CLASS: Mosaic Glass

DESCRIPTION: Mosaic glass is a decorative material used for external and internal facings of public buildings. It was found that mosaic glass could be formed by using a binder of 1% by weight of methyl cellulose, followed by sintering the glass at 500 degrees C for 30 minutes followed by 720 degrees C for 30 minutes.

CONTACT: Luoyang Institute of Building Materials, Luoyang, Henan Province, PRC

REFERENCE: "Sintered Mosaic Glass From Ground Waste Glass", Wansheng Liu, et. al., Glass Technology, February 1991, pp 24-27

CATEGORY: Building Materials
CLASS: Plastic-composite "Lumber"

DESCRIPTION: Sanders Enterprises has purchased the US rights of a European technology to manufacture "lumber" out of recycled plastic and glass cullet to build a product known as RecyWall. One linear foot of the wall, 12 feet high, uses 830 pounds of plastic and 220 pounds of glass. Built in modular sections, the wall can be up to 14 feet high and is then filled with compost or soil, with large openings for plantings. A model has been built for the Wisconsin Department of Transportation, and is on display at their Waukesha headquarters on Barstow Street.

CONTACT: Sanders Enterprises, Inc., 3019 Nash Road, Scott City, MO 63780, (314)334-9600

REFERENCE: "Recycled Wall", BioCycle, May 1993, page 88, visit to Waukesha headquarters of the Wisconsin Department of Transportation, June 9, 1993, literature from Sanders Enterprises, Inc., June 4, 1993

CATEGORY: Building Materials
CLASS: Plastic-composite "Lumber"

DESCRIPTION: Conversion Processing of Bloomington, MN says that it has developed a plastic-composite "lumber" using plastic, wood, glass and paper recovered from municipal waste to make fence posts, pallets, wheel chocks, and other products.

CONTACT: Conversion Processing, Bloomington, MN

REFERENCE: Resource Recovery, May 1993, page 63

CATEGORY: Building Materials
CLASS: Roof Shingles

DESCRIPTION: Shingles are made with recycled paper and glass, along with asphalt and cellulose with up to 15% post-industrial glass.

CONTACT: Atlas Roofing Corp., PO Box 5777, Meridian, MS 39301, (800)866-1476

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials
CLASS: Roof Shingles

DESCRIPTION: The University of Wisconsin has provided a grant to faculty at the UW-Green Bay to do a demonstration test to manufacture roofing shingles from scrap plastic and glass. They are using mixed grades of plastic and have had problems with getting them to fuse together. They have also run into problems with the large size of the locally available glass cullet; they had not anticipated needing to process it to a smaller size.

CONTACT: Nancy Sell, University of Wisconsin-Green Bay, Green Bay, WI, (920)465-2371

REFERENCE: Draft progress report dated February 1, 1995

CATEGORY: Building Materials
CLASS: Roof Tile

DESCRIPTION: The Metropolitan Service District of Portland, Oregon has given a grant to Wayne Fields for the development of a roof tile product from scrap glass containers.

CONTACT: Metropolitan Service District, Portland, OR

REFERENCE: Resource Recovery, May 1993, page 80

CATEGORY: Building Materials
CLASS: Skylights

DESCRIPTION: Skylights, windows, walls and other light diffusing products are produced partially with recycled glass.

CONTACT: Kalwall Corp., PO Box 237, Manchester, NH 03105, (603)627-3861

REFERENCE: The Harris Directory, The Stafford Architects, Seattle, WA, October 1994

CATEGORY: Building Materials

CLASS: Stone

DESCRIPTION: Great Harbor Design Center in Queens, New York will begin to make stone panels from container glass beginning in June, 2000. The stone is 1 inch thick and will be sold through Home Depot and possibly other outlets.

CONTACT: Tim McCarthy, CEO, Great Harbor Design Center, New York, NY

REFERENCE: "Harboring Hope for Recycling", Waste News, page 40, June 12, 2000

CATEGORY: Building Materials

CLASS: Terrazzo

DESCRIPTION: Resin Building Products Ltd in the UK is making a glass composite material that can be used for flooring, work surfaces and other purposes, under the name of TTURA.

CONTACT: <http://www.resbuild.co.uk> or <http://www.ttura.com/>

REFERENCE: Internet, March 20, 2003

CATEGORY: Building Materials

CLASS: Terrazzo

DESCRIPTION: American Terrazzo Company markets crushed recycled glass from the City of Plano, Texas under the name of EnviroGlas Terrazzo. The product is made with recycled glass and a colorful epoxy resin.

CONTACT: American Terrazzo Company, (972)272-8084, <http://www.americanterrazzo.com>

REFERENCE: "From Beer Bottle to Terazzo (sic) Flooring", Recycling Today, February 2003, page 16

CATEGORY: Building Materials

CLASS: Terrazzo

DESCRIPTION: The Dane County (WI) Public Works Department used ground up glass as an additive to epoxy terrazzo for decorative effect at its County Forum Building, built in the late 1990's

CONTACT: Jalaine Limbach, Dane County Dept of Public Works, 1919 Alliant Energy Center Way, Madison, WI 53713, (608)267-0127

REFERENCE: above

CATEGORY: Building Materials

CLASS: Terrazzo

DESCRIPTION: The Glass Containers Corporation of Fullerton, California has developed a process to produce terrazzo with glass cullet instead of marble. Know as "American Poly-Mod", the terrazzo with cullet has two to three times the flexural strength of conventional cement terrazzo. Abrasion and stain resistance are comparable to normal terrazzo, and low alkali cement avoids problems with glass-cement chemical reactions. The glass is found to economically be competitive with \$70 a ton marble; \$12 a ton glass results in a 9% reduction in the cost of the terrazzo.

CONTACT: Unknown

REFERENCE: Glass Recycling and Reuse, Harold R. Samtur, University of Wisconsin- Madison Institute for Environmental Studies Report 17, March 1974, 100 pages; also see "The Commercial Potential of Terrazzo with Waste Glass Aggregate", Glass Container Manufacturers Institute, 1973, 15 pages; "Refuse Glass Aggregate in Portland Cement Concrete", J. C. Phillips and D. S. Cahn, Proceedings of the Third Mineral Waste Utilization Symposium, 1972, page 390; and "Recycling Container Glass. An Overview", John H. Abrahams, Jr., Third Mineral Waste Utilization Symposium, March 14-16, 1972, pages 144-150

CATEGORY: Building Materials
CLASS: Wall Panels

DESCRIPTION: Wall panels and bricks were made consisted of 13%, 31% and 94% crushed glass, 6% clay, with the remainder crushed brick. Compression and modulus of rupture tests on the bricks made with these mixtures showed that they were much stronger than concrete and absorbed less water than concrete. The research also concluded that the cost of production was low. Part of the low cost was due to the lower firing temperature needed in using glass versus traditional ceramics.

CONTACT: unknown

REFERENCE: "New Building Materials Containing Waste Glass", T. C. Shutt, H. Campbell, and J. H. Abrahams, Jr., Bulletin. American Ceramic Society, 1972, pages 670-671

CATEGORY: Building Materials
CLASS: Wall Panels

DESCRIPTION: Prior to 1982, a wall panel was made under the name of Thixite and consisted of 13% to 94% crushed glass, 6% ball clay, and the remainder of other inorganic debris. Panels made of this material were used in an "ecology pavilion" in Denver, CO (possibly prior to 1972).

CONTACT: unknown

REFERENCE: "Process Design for the Production of a Ceramic-like Body from Recycled Waste Glass", I. W. M. Brown, K. J. D. Mackenzie, Journal of Material Science, 1982, page 2164

CATEGORY: Building Materials
CLASS: Wall Panels

DESCRIPTION: Thermalock Products, Inc. is testing the use of recycled glass to make insulated wall systems.

CONTACT: John Neff, Thermalock Products, Inc., 162 Sweeney Street, North Tonawanda, NY 14120.

REFERENCE: Randy Coburn, NY State Department of Economic Development, Office of Recycling Market Development, One Commerce Plaza, Albany, NY 12245, winter, 1992-93

CATEGORY: Building Materials
CLASS: Wall Panels

DESCRIPTION: A Rhode Island firm is working on a foamed insulation to make structural wall panels. (Note: this firm has subsequently moved to Massachusetts.)

CONTACT: David Solomon, President, Recycled Glass Products, Inc., Jamaica Plain, MA, (617)522-9695

REFERENCE: Personal correspondence from Marty Davey, Rhode Island DEM, January 24, 1996

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: The University of Sheffield is exploring alternative uses of glass in a \$ 2 million effort in partnership with 25 industrial partners. Projects include the use of glass in cement and concrete applications and as a polished or decorative finish for concrete products.

CONTACT: The University of Sheffield, Internet web page <http://www.shef.ac.uk>. Research project summaries found at <http://www.shef.ac.uk/materials/research/reseproj.html>

REFERENCE: "Glass", Resource Recycling, February 2003, page 38

---CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: Holnam Inc. of Three Forks, Montana will start making cement with recycled glass in December 1999. The firm has recently received approval from the Montana Department of Environmental Quality to use 800 tons of recovered glass in its cement. Holnam will replace sandstone in its cement recipe, according to Nicole Richinis, environmental manager for Holnam.

CONTACT: Nicole Richinis, Holnam Inc., Three Forks, Montana

REFERENCE: "Mont. Firm to Sub Glass in Cement Mixture in Vast State", Joe Truini, Waste News, November 22, 1999, page 4, "Cement Maker Uses 800 Tons of Glass per Year", Recycling Today, December 1999, page 18

---CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: Skedsmo Betongfabrikk AS [Skedsmo Concrete Factory AS] is the first concrete factory in Norway to produce concrete with the additive "Microfiller". Microfiller is a additive material which is made of crushed, ground and recycled glass. The grain size is between cement and fine gravel. The ground up glass functions as a lubricant in the concrete such that it becomes easier to work, pump, vibrate, etc, This makes concrete with glass additives well suited for dense reinforced construction. Mixing of the ground up glass takes place in the concrete mixer and the quantity of glass depends on the size and form of the other materials. Svensk Glas Återvinning AB [Swedish Glass Recycling], Cement och Betong Institutet [The Cement and Concrete Institute] and Essbetong developed Microfiller.

CONTACT: Unknown

REFERENCE: Web page of Norsas, the Norwegian solid waste association, press clipping from the magazine Ingeniørnytt, [Engineer News] October 8, 1999

---CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: After an intensive joint research between Norsk Glassgjenvinning [Norwegian Glass Recycling] (NGG) and SINTEF, a glass concrete has been produced as a commercial product for the building industry and which is a real alternative to natural stone. 75-80% of the glass concrete is glass. The glass concrete's structure and color can vary endlessly. Many small projects where glass concrete can be used are completed and it is planned to use blue glass concrete in the building of the museum for glass artists in Steinkjer. For this effort, the community will set out their own collection containers for blue glass. Lasse Sunde of NGG says that he hopes for help from many public building projects to establish the use of glass concrete and thereby insure the

sale of recovered glass within the country. These days, the collected glass must be transported to south Europe because of a saturated market for recyclable glass in the north.

CONTACT: Unknown

REFERENCE: Web page of Norsas, the Norwegian solid waste association, press clipping from the magazine Tur retur, nr 5/99

--- CATEGORY: Concrete Applications

CLASS: Concrete Additive

DESCRIPTION: Finely ground glass (minus 200 mesh) can act as a pozzolan, reacting with the alkali in cement in a uniform manner, thereby reducing the alkali-silica reaction with the other aggregates of concrete.

CONTACT: Unknown

REFERENCE: Glass Recycling and Reuse, Harold R. Samtur, University of Wisconsin- Madison Institute for Environmental Studies Report 17, March 1974, 100 pages; also see "Glass as a Pozzolan", M. Pattengil, Albuquerque Symp. Util. Waste Glass Sec. Prod., 1973

CATEGORY: Concrete Applications

CLASS: Concrete Additive

DESCRIPTION: Research was done on the use of glass and several alternative polymers to use as an additive to concrete to make sewer pipe. Advantages sought were resistance to attack from acidic materials, lighter weight and possible greater strength. Pipe manufactured with scrap glass and a polyester-styrene polymer were manufactured and installed in a test project in the Town of Huntington, Suffolk County [NY?] in 1972. Future work was to focus on simpler methods of manufacturing the pipe.

CONTACT: unknown

REFERENCE: "Glass-Polymer Composites for Sewer Pipe Construction", Meyer Steinberg and Morris Beller, Proceedings of the Fourth Mineral Waste Utilization Symposium, 1974, pp 162-173

CATEGORY: Concrete Applications

CLASS: Concrete Additive

DESCRIPTION: By adding an inorganic binder, such as albino clay (an aluminum-silicate kaolin-type clay), or a synthetic cation exchange resin, it is possible to overcome the alkali-silica reaction that takes place between cement and glass reinforcing material in cementitious products.

CONTACT: Corning Fiberglass Corporation

REFERENCE: Patent 3,147,127, 1964

CATEGORY: Concrete Applications

CLASS: Concrete Additive

DESCRIPTION: By adding small glass beads from soda lime glass to concrete mixtures in accordance with this invention, the concrete has improved adhesion as an overlay. The glass should be from 2.6 to

233 mesh (0.0661 to 0.0024 inches), and added at a level of 0.1% to 1.5% to a mixture of 20 to 66 parts by weight of Portland cement and 80 to 34 parts by weight of sand.

CONTACT: Alex Jansen, 3812 N. Odell, Chicago, IL 60634 (1974 address)

REFERENCE: Patent 3,823,021, 1974

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: Various forms of glass - filaments, fibers, hollow spheres, and foam glass - can be added to cement, mortar or concrete to improve the tensile and compression strength, impact strength and abrasion resistance. However, the use of fibers or hollow spheres made of conventional glass results in a long term chemical reaction that weakens the concrete or cementitious products . This invention overcomes these reactions by selecting the composition of the glass to be added to contain specified amounts of metallic oxides of the following three conditions:

First - the composition is as follows:

| Component | Wt % | Component | Wt % |
|--------------------------------|-------|------------------|------|
| SiO ₂ | 20-70 | TiO ₂ | 3-12 |
| ZnO | 5-70 | CuO | 0-10 |
| Fe ₂ O ₃ | 0-5 | BaO | 0-30 |
| CaO | 0-10 | MgO | 0-15 |
| Al ₂ O ₃ | 0-30 | | |

Second - the ratio of the molar sum of Al₂O₃+MgO+CaO to the molar sum of ZnO+CuO+TiO₂+Fe₂O₃ is less than or equal to 0.5.

Third - metallic oxides from the group of As₂O₃, Sb₂O₃, V₂O₅, B₂O₃, PbO, CdO, SnO₂ and M₂O (where M is an alkali metal) is less than 0.4 mole percent.

CONTACT: Jenaer Glaswerk Schott & Gen., Mainz, Germany

REFERENCE: Patent 4,002,482, 1977

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: This invention inhibits the alkali-silica reaction that occurs between cement and glass reinforcing materials by coating the glass with a water- soluble zinc salt. The most practical method of applying the zinc salt is as a sizing compound.

CONTACT: Jenaer Glaswerk Schott & Gen., Mainz, Germany

REFERENCE: Patent 4,013,478, 1977

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: This invention is an inhibitor of the alkali-silica reaction that occurs in concrete that has glass reinforcing materials. The inhibitor is a finely ground alkali-reactive material with silica, and has a substantially greater reactivity than does the glass reinforcement material, causing the

alkali of the cement to react with the inhibitor rather than the glass reinforcement. Two inhibitors tested were commercial silica flour, 325 mesh, 97% SiO₂ and ground soda-lime glass ground to pass 100 mesh, containing 69% SiO₂. It was found that a basic criteria for an effective inhibitor was to have the solubility of the inhibitor at least twice that of the reinforcement; the soda-lime glass was superior to the silica flour in this respect. The patent also provides an equation for the quantity of inhibitor to use. It was found that the resulting mixture was particularly effective as a surface coating material for concrete block.

CONTACT: W. R. Bonsal Company, Lilesville, NC

REFERENCE: Patent 4,090,884, 1978

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: This invention inhibits the alkali-silica reaction that occurs between cement and glass reinforcing materials by adding a reactive alkali compound and a water soluble salt of barium, lithium or zinc. The metal salts should be finely ground and well mixed in the concrete. The salts should be present in quantities equal to 0.5% to 50% (by weight) of the glass reinforcement, although the benefits seem to level off at about 10% to 15%.

CONTACT: W. R. Bonsal Company, Lilesville, NC

REFERENCE: Patent 4,115,135, 1978

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: Alkali resistant glass can be formed by using between 18% and 24% ZrO₂.

CONTACT: Nippon Sheet Glass Company

REFERENCE: Patent 4,243,421, 1981

CATEGORY: Concrete Applications
CLASS: Concrete Additive

DESCRIPTION: The Clean Washington Center is doing trials with the use of glass as an additive or fine aggregate in making cement or concrete products. Their conclusion is that the concrete should not be used as a structural material because of the weakness caused by the alkali-silica reaction, but that it can be used for other items where the glass provides aesthetic properties; as an example, a plastering contractor regularly uses glass in a "hybridized portland cement" plaster. A fact sheet on minimizing the alkali-silica reaction is to be available in March 1995.

CONTACT: Bob Kirby, CWC, (206)443-7746; email kirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995

CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: A pilot plant is being established by Elizabeth City Glass to produce fused-glass products, including concrete aggregate, sandblasting abrasives, pavers, floor and wall tiles, drainage pipe, and filter media.

CONTACT: Shawn Lemmond, Elizabeth City Glass, North Carolina

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

--- CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: Recycled glass was found to be technically and economically feasible for use as cement in concrete masonry block, according to a short summary of the report "Use of Recycled Glass as Concrete Masonry Blocks", PG98-158934WEP.

CONTACT: National Technical Information Service, 5285 Port Royal Road, Springfield, V 22161, (800)553-6847, <http://www.ntis.fedword.gov>

REFERENCE: Resource Recycling, November 1998, page 44

--- CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: A patent was granted to Columbia University for the use of waste glass in concrete masonry block.

CONTACT: patent 5,810,921

REFERENCE: Resource Recycling, November 1998, page 11

CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: In Thurston County, Washington, two entrepreneurs have developed a concrete using mixed color glass as the aggregate. The concrete was used to build bird houses, but later discontinued because it was so labor intensive. Instead, they turned their attention to building paving squares with a smooth, glazed surface, along with garden landscaping bricks, home planters, table tops and candle holders. At the time the article was written, the firm had 50 molds and produced about 300 pieces a month.

CONTACT: Scatter Creek Enterprises, Rochester, WA

REFERENCE: "Colored Cullet makes Products Sparkle", Mary E. Harrington, BioCycle, September 1998, pages 68-69

CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: In Scottsdale, AZ, the city is working with a private firm (Enviro Sand, Inc.) to grind glass bottles into six different sizes, including marble size pieces for landscaping as well as art objects, sand for use in ashtrays and as an additive in concrete and stucco, and chalk for painting lines on baseball fields.

CONTACT: Dennis Enriquez, City of Scottsdale environmental coordinator, Dave Columb, President, Enviro Sand

Inc.

REFERENCE: "Glass Breads Into Pebbles in Ariz.", Bruce Geiselman, Waste News, June 8, 1998, page 17

--- CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: The National Technical Information Service has published a book titled "Use of Recycled Glass and Fly Ash for Precast Concrete", which presents the results of research conducted by the Columbia University Department of Civil Engineering and Engineering Mechanics. The research sought to develop an attractive material for use in architectural and decorative concrete applications. The report is 144 pages long, and is numbered PB99-133118WEP.

CONTACT: NTIS, 5285 Port Royal Road, Springfield, VA 22161, (800)553-6847, orders@ntis.fedworld.gov

REFERENCE: Resource Recycling, August 1999, page 58

---CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: At Columbia University, research is being done on the use of glass as a component of making concrete block. Over 2,600 specimens of concrete with glass will be made, testing different types of cement, different levels of glass, different sizes of glass, different types and quantities of inhibitors of the alkali-silica reaction, etc. Included in the project will be treatment of the glass to improve its bonding with the cement. The project was funded in early 1995 and is expected to take 2 years.

As of November 1995, the goal was to focus on a level of about 10% glass, focusing on a substitution of the gravel, not the sand. It was believed that concrete block is so porous, and the strength of the concrete is so much higher than what is needed that any expansion of the cement due to an alkali-silica reaction will not be a problem -- the pores will be able to take up the expansion, and the strength will still be above what is needed. It appears that the economics will be dependent on the cost to handle the glass prior to incorporation into the blocks, especially any needed washing costs.

As of May 1996, the results look very promising, and the data will be released soon. One of the logistical problems to be solved is to economically wash the glass to remove labels and food debris, especially the sugars. One potential system would then color-sort the glass to remove the clear for sale to the container or other end users, and only use the lower value green and brown glass cullet for incorporation into the blocks.

The researchers are also applying for a second grant to explore the use of glass in forms.

CONTACT: Stephen Baxter, c/o Christian Meyer, Columbia University, Dept of Civil Engineering, 500 West 120th Street, New York, New York 10027, (212)854-5606

REFERENCE: Telephone conversations with Stephen Baxter, July 1994, November 15, 1995 and May 7, 1996; technical proposal prepared by Christian Meyer and Stephen Baxter, August 17, 1994; Engineering News-Record, May 22, 1995, pp 26-27; also see Concrete International, June 1995, page 15

CATEGORY: Paving Applications

CLASS: Concrete Aggregate

DESCRIPTION: The use of glass cullet as an aggregate in concrete has being tested in laboratory work at the University of Wisconsin-Madison, using various mixtures of glass, different types of cement

(including low-alkali cement), and fly ash from coal burning facilities. The experiments were especially aimed at overcoming the alkali-silica reaction that tends to occur in glass-cement mixtures, which results in a weakening of the cement. Based on the laboratory experiments, test sidewalk pavement was laid in the summer of 1994, using a control without fly ash, a control with fly ash, and 4 mixes with 10%-20% glass and 15%-25% fly ash. As of November 1995, some of the lab and field results have been favorable, while others have indicated a problem. Compressive strengths after one year were between approximately 6000 to 7000 psi, and still increasing rapidly, while expansion after one year was 0.008% to minus 0.008%. The freeze-thaw test had initially proved satisfactory -- after about 90 cycles, there was a relative elastic modulus of between 93% and 98% --but then the results fell off rapidly, and after 400 cycles, the relative elastic modulus declined to a range of about 65% to 77%. However, the controls also had poor results, at approximately 79% to 82%. The results are being reviewed to determine the next steps. Initial plans had called for the laying of road pavement in 1996.

CONTACT: John Reindl, Recycling Manager, Dane County Department of Public Works, 1919 Alliant Energy Center Way, Madison, WI 53713, (608)267-8815 or Steve Cramer, Professor of Civil & Environmental Engineering, University of Wisconsin, Room 2266, 1415 Johnson Drive, Madison, WI 53706, (608)262-7711

REFERENCE: Same, April 1996

CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: This invention processes glass cullet to both provide roughness to the smooth surface of glass cullet as well as smoothing the sharp edges found on normally crushed glass. First, the cullet is crushed to a mesh size of A32 to B32. The crushed cullet is processed by grinding in a rotating drum that has a grinding agent, water and hydrofluoric acid as an etching agent. There was no description of any testing of this material in concrete, however.

CONTACT: Patrick Lamoni, Via Cattedrale 14, 6900 Lugano, Switzerland

REFERENCE: Patent 4,997,485, 1991

---CATEGORY: Construction Applications
CLASS: Concrete Aggregate

DESCRIPTION: A three phase study was done on the use of glass as an aggregate in concrete. Using amber colored glass, a high alkali cement was ground to a finer size than normal to produce a larger surface area. The three phases were as follows: (1) laboratory tests to determine the optimum replacement of natural aggregate with glass, (2) casting of masonry blocks using the data of the first phase and doing short term tests of engineering properties, and (3) long term testing of the masonry blocks to determine any glass-cement reactions. The glass was washed to remove sugar and crushed, but the size distribution was not given. In the first two phases, it was found that the strength of the concrete decreased linearly with the percentage of glass added, but a 35% replacement of natural aggregate with glass still produced a concrete that exceeds engineering standards. Shrinkage and moisture absorption also met industry standards if the concrete were used to make foundation block. At the time of the presentation of this paper, the long term tests had only proceeded for 6 months, although a 2 year test was envisioned. Preliminary results did not indicate a significant glass-cement (alkali- silica) reaction. [Compiler's note: I looked for a follow-up article in the 4th through 7th mineral waste utilization symposia, but was not able to find anything.]

CONTACT: Unknown

REFERENCE: "Refuse Glass Aggregate in Portland Cement Concrete", J. C. Phillips and D. S. Cahn, Proceedings of the Third Mineral Waste Utilization Symposium, 1972, pages 385-390

CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: The US Bureau of Mines sponsored research on the recovery of glass for a variety of uses, including using waste glass from municipal incinerator residue as an ingredient in lightweight aggregate for concrete. The glass was ground to a minus 200 mesh, combined with a mixture of clay and sodium silicate, pelletized, heated to create an expanded aggregate and crushed to less than 1/2" for use in the concrete. The concrete was tested for 28-day strength and found to meet applicable ASTM standards, including requirements for controlling the alkali-silica reaction.

CONTACT: Unknown

REFERENCE: "Waste Glass as an Ingredient of Lightweight Aggregate", Reynold Shotts, Proceedings of the Third Mineral Waste Utilization Symposium, March 14- 16, 1972, pages 411-422; "Lightweight Structural Concrete Aggregate from Municipal Waste Glass", K. J. Liles, Proceedings of the Fifth Mineral Waste Utilization Symposium, 1976, pages 220-222; and Report of Investigations 8104, US Bureau of Mines, "Waste Glass as a Raw Material for Lightweight Aggregate", K. J. Liles, and M. E. Tyrrell, Tuscaloosa Metallurgy Research Laboratory, Tuscaloosa, AL, 1976

CATEGORY: Concrete Applications

CLASS: Concrete Aggregate

DESCRIPTION: Research was done on the potential use of glass cullet as a coarse aggregate (approximately 3/4") in concrete, either by itself (replacing the gravel aggregate) or in conjunction with gravel, using both low alkali (0.58%) and high alkali (1.13%) cement, and both with and without fly ash (type not specified). Forty combinations were formulated and tested for compressive strength, flexural strength and expansion. Tests were run at intervals of up to a year in length. For compressive strength, it was found that the fly ash improved the strength of both the low alkali and the high alkali mixtures, with the greatest strength at the highest rates of substitution (25-30%). Low alkali cement produced the strongest mixture, both with and without the fly ash. The compressive strength of the high alkali cement without the fly ash was not adequate for use as concrete; all other combinations were suitable and had at strengths of at least 2,500 psi. For the low alkali cement without fly ash, there was a peak in 365-day compressive strength at 600 pounds of cement per cubic yard of concrete. For flexural strength, the results were similar to compressive strength. The flexural strength of the low alkali cement without fly ash increased rapidly with increased cement use up to 600 pounds of cement per cubic yard, and declining slowly as more cement was added. In both compressive strength and flexural strength, the screening of the glass to remove fines had only a minor impact on strength, while the mixtures of gravel and glass resulted in large strength losses as compared to gravel alone. In the expansion tests, the low alkali cement mixtures using 600 pounds of cement or less per cubic yard exhibited satisfactory results without the addition of fly ash. Using fly ash, 700 pounds per cubic yard of low alkali cement could be used satisfactorily with fly ash comprising 25%-30% of the cement. For high alkali cement, only a mixture of 30% fly ash produced adequate results, again using 700 pounds of cement per cubic yard. No freeze-thaw tests were reported to have been done.

CONTACT: Unknown

REFERENCE: "Waste Glass as Coarse Aggregate for Concrete", C. D. Johnston, Journal of Testing and Evaluation, 2(5):344-350, September 1974

CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: Prior to 1972, the Fullerton, CA Air Industrial Park used amber glass as an aggregate in the wall lining the park. The wall was wire brushed to expose the glass to produce a decorative finish.

The American Cement Company and the Glass Containers Corporation made the tests using amber glass and low alkali cement, and found that with 35% cullet, the concrete still passed ASTM tests for volume expansion and water absorption. However, compressive strength decreased with increased glass content.

CONTACT: unknown

REFERENCE: "Refuse Glass Aggregate in Portland Cement Concrete", J. C. Phillips and D. S. Cahn, Proceedings of the Third Mineral Waste Utilization Symposium, 1972, page 390; Glass Recycling and Reuse, Harold R. Samtur, University of Wisconsin-Madison Institute for Environmental Studies Report 17, March 1974, 100 pages

---CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: The use of waste glass as an aggregate in concrete tends to lower the strength of the concrete because of the alkali-silica reaction. Replacement of the cement with 20-30% fly ash is effective in controlling the loss of strength. Waste glass can also be used to make lightweight (expanded) aggregate of 528 kg/m³ by pelletizing a mixture of ground waste glass, clay and sodium silicate and heating to about 850 degrees C. Problems with using glass include the contamination and the elongated particle size, which is not suited for use in concrete. Sugar- contaminated glass should be cleaned well if used in concrete.

CONTACT: Unknown

REFERENCE: "Waste and By-Products as Concrete Aggregates", V. S. Ramachandran, Canadian Building Digest, April 1981, pages 215-1 to 215-4

CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: The Solid Waste Authority of Palm Beach County, Florida is testing the use of recycled glass to replace traditional aggregates in concrete block concrete, and roofing.

CONTACT: Tim Whelan, Recycling Markets Manager, Solid Waste Authority of Palm Beach County, Florida, 7501 North Jog Road, West Palm Beach, FL 33412, (407)471-2700.

REFERENCE: Same, winter 1992-93

CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: Econo Block of Medford, WI is manufacturing "plasticrete" block out of recycled materials, including glass cullet, plastic, and wire mesh from defunct mink cages. The company is using 19 tons of glass a month for their production, and can use any plastic except polystyrene. The firm has been working on this process for about a year, especially intensively for the last 6

months. They process the glass to the size of sand or smaller, but didn't have information on the actual size or gradation. They use a range of formulations, but as an example, for their 20" by 20" by 3" block, they use a mixture of 26 pounds of glass, 15 pounds of plastic, and 90 pounds (one sack) of LaFarge I cement. No other aggregate is used. This mixture makes about 5 to 5½ blocks. Testing of the brick found that compression strength was about 3,250 psi, and that the blocks survived 25 years' of freeze-thaw cycles (at 6 cycles per year). The blocks were not tested either for expansion or the impacts of alkali-silica reactions. As of September 8, 1993, the partners of this firm had split up and the company was out of business.

CONTACT: Scott Lemke or Shelly Blasel, Econo Block, N1812 Apple Ave, Medford, WI 54451, (715)678-2989 or (715)767-5387

REFERENCE: Telephone conversation with Scott Lemke, April 22, 1993; conversation with Norm Kleinstick of the Taylor County Solid Waste Management Committee, September 8, 1993

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CATEGORY: Concrete Applications
CLASS: Concrete Aggregate

DESCRIPTION: Columbia University has developed a process to use crushed glass as an aggregate in concrete, which is estimated to have the potential to use 13 million tons of glass annually. Columbia has majority ownership in a business – Echo Environmental – which will market and license the technology.

CONTACT: Echo Environmental, <http://www.echoenvironmental.com/>, accessed March 8, 2002, 60 Broad Street, 35th Floor, New York, NY 10004, (212)363-8181 ext 130.

REFERENCE: "Walking on Glass", Joe Truini, Waste News, December 11, 2000, and "Concrete Materials Research at Columbia University", Department of Civil Engineering and Engineering Mechanics, August 2000, pages 8-11, 14-21, 38-40

CATEGORY: Concrete Applications
CLASS: Concrete

DESCRIPTION: A private firm in Wisconsin has used crushed glass in concrete in both laboratory samples and test slabs. The tests used approximately 124 pounds of crushed glass with 3000 pounds of aggregate and 564 pounds of cement. In the laboratory samples, the short term compression tests found that the concrete was sufficient strong enough to meet recognized tests, with 7-day strengths of 4100-5000 psi, and 28-day strengths of 5,190-5,820 psi. The firm is furthering its work by looking at the long-term characteristics of this concrete used in slabs.

CONTACT: Ray Selk, Chicago Art Glass and Jewels, Inc. 937 Pilgrim Road, Plymouth, WI 53073, (920)892-2744

REFERENCE: Final report to the Wisconsin Department of Natural Resources on a demonstration grant for recycling glass, December 1992

CATEGORY: Concrete Applications
CLASS: Concrete

DESCRIPTION: In England, WD Consultants tested the possibility of using powdered glass in concrete to possibly fill the voids or to otherwise affect the chemical reactions. However, preliminary work showed an un-named effect that had not occurred before, and a long term study has been set up to study the cement reactions where powdered glass is present, since it can take up to two years for all the reactions to be completed.

CONTACT: Unknown

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256-258

CATEGORY: Concrete Applications

CLASS: Concrete

DESCRIPTION: A firm in the state of Washington is making cullet-concrete products, such as birdbaths, border edging, tables, and stepping stones.

CONTACT: Scatter Creek Enterprises, Rochester, WA

REFERENCE: "Glass", Resource Recycling, June 2001, page 41

NOTE: Also see CATEGORY: Paving Applications, CLASS: Concrete

CATEGORY: Construction Aggregate
CLASS: Aggregate Base Course

DESCRIPTION: The Town of Portage La Prairie, Manitoba is using crushed glass as an underlay for cement sidewalks.

CONTACT: Tim Teeple, Portage Area Recycling, Box 515, Portage La Prairie, Manitoba, R1N 3B9

REFERENCE: Glen Korolvk, Recycling Council of Manitoba, 1812-330 Portage Avenue, Winnipeg, Manitoba, R3C 0C4, winter, 1992-93

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: Winneshiek County, Iowa is using crushed glass as drainage material in the construction of landfill cells.

CONTACT: Terry Buenzow, at Spectrum Recycling, 2510 172 Ave., Decorah, IA 52101 or (563)382-6514

REFERENCE: Email messages from Heidi Sweet, Spectrum Recycling, Decorah, Iowa, February 20 and March 25, 2003

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: A private firm, Zanker of San Jose, CA, used 4,000 tons of ground waste glass in its landfill leachate system.

CONTACT: Unknown

REFERENCE: "Market Status Report. Glass", California Integrated Waste Management Board, July 23, 1992, page 30

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: The 1991 National Standard Plumbing Code allows the use of glass crushed to 3/4" as aggregate in storm drains, which are used to drain water away from the parts of buildings that are below ground. At least 4" of porous material is required around storm drains.

CONTACT: unknown

REFERENCE: "Waste Glass Container Markets in the Wisconsin Region. Executive Summary", Resource Management Associates, Napa, CA, July 1992, page VI-23

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: Crushed glass is used as an aggregate in fabric sleeves to replace perforated plastic underdrain pipes. It is said that the construction of a typical 1,250 square foot house could use 2 tons of glass. The firm is franchising this system, with 4-5 franchises said to be under discussion as of March, 1992.

CONTACT: Bill Kozak, Glass Aggregate Corporation, 2020 Monroe, NW Grand Rapids, MI 49505, (616)363-9801

REFERENCE: "The Nitty Gritty of Glass Recycling: Glass Residue Market Study", August 1991, produced for the Rhode Island Dept of Environmental Management and the RI Solid Waste Management Commission; Resource Recycling, October 1991, page 73; and "Creating Local Jobs from Environmental Protection. Focus on Recycling and Small Business", March 1992, T. Paul Robbins, et. al., (city, organization unknown; received from Erv Sandlin, Texas Water Commission)

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: The City of Seattle has used (processed) glass bottles for drainage aggregate at its landfill.

CONTACT: Unknown

REFERENCE: Resource Recycling, February 1993, page 70

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: In New London, NH, Richard Lee, the road agent, has developed a machine to attach to the back of a sand spreading truck in which glass is crushed and screened to a size of 1/2" minus. The resulting material, often called PGA in New Hampshire, is being used for fill around sewer connections from homes to the city's line, as fill for electrical conduit, as backfill and drainage aggregate along walls, and as frost heave protection fill under pathways and parking lots. The machine was built by the city at a cost of under \$1,200 and is powered by the truck's hydraulics.

CONTACT: Richard Lee, New London, NH

REFERENCE: Peg Boyles, NHRRA, in a May 24, 1993 telephone conversation

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: Palm Beach County, FL has used mixed cullet from its MRF for drainage aggregate at its landfill in french drains.

CONTACT: Scott Riemer, The Solid Waste Authority of Palm Beach County, FL (407)471-2700

REFERENCE: Personal telephone conversation, February 13, 1995

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: Schenectady County, NY is pulverizing glass with an Andela glass system, and is testing the use of the crushed glass for backfilling drainage tile lines at the County farm and for use by local farmers.

CONTACT: John Hewitt, Site Manager, Schenectady County Recycling Facility

REFERENCE: Waste Handling Equipment News, October 1995, page 1+

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: In Denver, the local government and Coors are using crushed cullet for drainage ditch liners and in pavement.

CONTACT: Unknown

REFERENCE: "Southwestern Recyclers Learn the Latest at Annual Conference", Recycling Times, c. November 1995, pages 10, 12

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: In 1993, the Iowa DNR funded a pilot project for the use of cullet as an underdrain material at the South Central Iowa Sanitary Landfill near Winterset.

CONTACT: Marcia Beeler, South Central Iowa Landfill Agency, (515)462-3083

REFERENCE: Personal correspondence from Jeff Geerts, Iowa DNR, January 10, 1996

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: The South Carolina Department of Transportation is developing specifications for using cullet in embankment and french drains. It is in draft form, and has not been field tested as of March 1996.

CONTACT: Mohammed Araim, South Carolina Department of Transportation, Research & Material Lab, PO Box 191, Columbia, SC 29202, (803)737-6701

REFERENCE: Telephone conversation with Mohammed Araim, March 15, 1996

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: Glass cullet is being used in a small community in northern Arkansas as fill under concrete in drainage ditches.

CONTACT: Robert Hunter, Arkansas Recycling Coordinator, (501)563-6533

REFERENCE: Personal letter from Robert Hunter, February 7, 1996

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: The Town of Dryden, Ontario uses cullet for drainage aggregate in trench drains and in French drains in parkland and residential subdivision work. The Town has also provided cullet to the private sector for use over weeping tile in new house construction.

In addition, the town has used cullet as base aggregate in road construction, mixed at 10% or less with pit run gravel and is negotiating with the province to use cullet as a drainage aggregate in septic field construction.

CONTACT: M. Fisher, Town of Dryden, 30 Van Horne Avenue, Dryden, ON P8N 2A7, (807)223-2367

REFERENCE: Personal letter from M. Fisher, May 13, 1996

CATEGORY: Construction Aggregate
CLASS: Drainage Aggregate

DESCRIPTION: The Schenectady County Soil & Water Conservation District of Scotia, NY tested the use of processed glass as an envelope around agricultural pipe and found it suitable. The tests were funded by the New York Office of Recycling Market Development and included the placement and testing of coarse glass in 11 drainage sites.

CONTACT: Schenectady County Soil & Water Conservation District, Scotia, NY

REFERENCE: Resource Recycling, August 1999, page 55

--- CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: A regional facility has been developed to accept recyclable glass (including both bottles and window glass), ceramic and porcelain to process into a gravel replacement for use by the city of Goffstown, NH.

CONTACT: Northeast Resource Recovery Association, Chichester, New Hampshire

REFERENCE: Resource Recycling, June 2003, page 36

--- CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: Durango, Colorado is using processed glass to fill sandbags which are then used to line streams to prevent forest fire debris from washing downstream. Other uses include leach fields, in pipe bedding, as a mulch or a landscape material. About 450 tons of material are processed a year and sells for about \$10 a ton.

CONTACT: City of Durango, Colorado

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13, "Glass", Resource Recycling, February 2003, page 38

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: Echo Environmental has established an agreement with a major university to market construction building products that use mixed color waste glass as an aggregate. The firm has developed a process to suppress the alkali-silica reaction that occurs between the alkali in the cement and the silica in the glass. The product is said to be less expensive than conventional concrete.

CONTACT: Unknown

REFERENCE: "Recycled Glass as Construction Aggregate", Glass Industry, November 1999, page 8

---CATEGORY: Construction Aggregate

CLASS: General

DESCRIPTION: CWC has taken the previous work of the Clean Washington Center with its 5 volume report "Glass Feedstock Study" and combined this information with case-study experiences to prepare "A Tool Kit for the Use of Post-Consumer Glass as a Construction Material".

The Tool Kit contains information on the geotechnical, engineering, physical and chemical properties of glass cullet, equipment for processing glass, and specifications from several state transportation departments. Also included are six case studies, using from 34 to 12,000 tons of glass for general fill, drainage, wall backfill and under-slab fill.

CONTACT: Bob Kirby, CWC, (206)587-5520, kirbgood@aol.com, <http://www.cwc.org>

REFERENCE: "Construction Aggregate from Scrap Glass", Bob Kirby, Resource Recycling, May 1998, pages 48-50

---CATEGORY: Construction Aggregate

CLASS: General

DESCRIPTION: The State of Hawaii has enacted a law (Act 213-92) to require the use of glass cullet in non-structural construction projects, such as cushioning backfilling of underground utilities, drainage backfill behind retaining walls, drainage backfill surrounding leachlines and perforated drains, and similar uses.

CONTACT: John Harder, Office of Solid Waste Management, 5 Waterfront Plaza, 500 Ala Moana Blvd, Honolulu, HI 96813

REFERENCE: Same, winter 1992-93

CATEGORY: Construction Aggregate

CLASS: General

DESCRIPTION: The Director of Public Works in Plymouth Township, Montgomery County, Pennsylvania was seeking information on using recycled in the construction and building trades, i.e., roadway construction and repair, pipe installation, etc.

CONTACT: Timothy Boyd, Director of Public Works, Plymouth Township, (215)277-4103

REFERENCE: PenCycle BBS, February 3, 1992

CATEGORY: Construction Aggregate

CLASS: General

DESCRIPTION: The New Hampshire Governor's Recycling Program has completed a study of crushed glass and ceramic containers for use as Processed Glass Aggregate (PGA) as fill, drainage aggregate and as roadbase material. The project proved successful and the NH Resource Recovery Association has received a grant to promote its use.

CONTACT: Elizabeth Bedard, Governor's Recycling Program, Office of State Planning, 2 1/2 Beacon Street, Concord, NH 03301, (603)271-1098

REFERENCE: Personal Correspondence with Elizabeth Bedard, April 9, 1993

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: The Clean Washington Center led a consortium of states, local government and private firms in having an evaluation done on the properties of glass cullet for use as construction aggregate for base course for roads, landfill cover, septic fields, sandblasting, french drains and similar uses. Dames & Moore did the actual work and published a summary brochure and five documents:

- Testing Program Design Report
- Environmental Suitability Evaluation
- Equipment Evaluation
- Engineering Suitability Evaluation
- Evaluation of Cullet as a Construction Aggregate

Four major conclusions were reached:

1. The engineering performance of cullet for 13 criteria showed it to be an excellent supplement or replacement for gravel in many construction applications.
2. No appreciable environmental impact could be detected from the use of glass.
3. Since glass contains amorphous silica rather than crystalline silica, it does not pose the health risks associated with sand. Bottle cullet also does not normally cause skin cuts.
4. The economics are very case and geography specific, but can be competitive with or less expensive than conventional aggregates.

CONTACT: Clean Washington Center, 999 3rd Avenue, Suite 1060, Seattle, WA 98104, (206)443-7746

REFERENCE: Summary brochure, 8 pages, Engineering Suitability Evaluation, 103 pages, and Evaluation of Cullet as a Construction Material, 23 pages, all June 1993, "Using Glass as Construction Aggregate Feedstock", C. J. Shin and Victoria Sonntag, presentation at the Transportation Research Board, January 9-13, 1994, Washington, DC, 26 pages, Paper No. 940687

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: Wheelabrator Environmental Systems, Inc. used 5,000 cubic yards of mixed cullet for the foundation of a MRF it built in Falls Township, PA.

CONTACT: Patrick Scanlon, Director of Recycling, Wheelabrator Environmental Systems, Inc.

REFERENCE: BioCycle, May 1994, page 21, and August 1994, page 65, Recycling Times, August 9, 1994

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: Whatcom County, WA has approved the use of glass cullet as a construction aggregate such as road building, backfill for utility lines or as a substitute for gravel in construction activities. However, they will not allow its uses for regrading or fill, in areas of substantial erosion, or in areas of extremely low or high pH (because of concern for leaching lead from the glass).

CONTACT: Jeanne Funsch, Whatcom County Health Department, PO Box 935, Bellingham, WA 98227-0935

REFERENCE: Letter from Jeanne Funsch to Jack Weiss, March 23, 1994

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: The State of Wisconsin has issued an exemption for the use of recycled glass in asphalt, roadbed aggregate and drain tile material in state code NR500.08. The code can be found on the Internet at <http://www.legis.state.wi.us/rsb/code/nr/>

CONTACT: Wisconsin DNR, PO Box 7921, Madison, WI 53707, (608)266-2111

REFERENCE: Email from Paul Wiegner, Wisconsin DNR, May 7, 1998

CATEGORY: Construction Aggregate
CLASS: General

DESCRIPTION: The State of Washington Department of Transportation has amended its specifications to allow the use of recycled glass aggregate in 17 applications. Two broad categories of standards are established. In the first category (9-03.21(1)), for 11 products (ballast, shoulder ballast, crushed surfacing base course, aggregate for gravel base, gravel backfill for foundations (class A and class B), gravel backfill for drains, bedding material for rigid pipe, foundation material (class A and B and class C) and bank run gravel for trench backfill), no more than 15% glass can be used, and no more than 10% of the material retained on a 1/4 inch screen shall be glass. In the second category (9-03.21(2)), for 6 products (gravel backfill for walls, gravel backfill for pipe bedding, backfill for sand drains, sand drainage blankets, gravel borrow, and bedding material for flexible pipes), 100% of the material shall pass a 3/4 inch sieve, and no more than 5% pass a US No. 200 sieve. Debris shall be a maximum of 10%, and total lead (such as from lead foil) shall either be less than 80 ppm or at a 90% confidence level of being less than 100 ppm. The testing for this second category shall be done at least quarterly.

CONTACT: Washington Department of Transportation or Clean Washington Center, 999 3rd Avenue, Suite 1060, Seattle, WA 98104, (206)443-7746

REFERENCE: Resource Recycling, September 1994, page 94; "Glass. ReTAP Technology Brief. Specifications for Glass Aggregate: Washington State Department of Transportation", Clean Washington Center fact sheet #RTB1G1, September 1994

CATEGORY: Construction Aggregate
CLASS: Highway Fill

DESCRIPTION: The Florida State Department of Transportation has prepared a series of publications on using scrap as highway fill. Distributed by the federal National Technical Information Service (NTIS), volume 2 of the series covers scrap glass as highway fill.

CONTACT: NTIS, (800)553-6847. Ask for Volume 2. Waste Glass. Development Specifications for Waste Glass, Municipal Waste Combustor Ash and Waste Tires as Highway Fill Materials (Continuation): Final Report, PB98-144207WEP

REFERENCE: Resource Recycling, September 1998, page 62

---CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: Palm Beach County, FL uses mixed color cullet from its MRF for part of the cover of its landfill.

CONTACT: Scott Riemer, The Solid Waste Authority of Palm Beach County, FL (407)471-2700

REFERENCE: Personal telephone conversation, February 13, 1995

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: The City of Seattle has used (processed) glass bottles for part of the cover of its landfill.

CONTACT: Unknown

REFERENCE: Resource Recycling, February 1993, page 70

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: The Oneida/Herkimer County, NY, MRF processes about 5 tons of cullet a day for use as landfill cover and as road bed material.

CONTACT: Steve DeVan, Oneida/Herkimer County MRF, Utica NY, (315)733-1224

REFERENCE: Personal communication from Andela Tool & Machine Co, August 1995

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: The Madison County, NY recycling center processes cullet for use as landfill cover, to make temporary landfill roads, and for fill in drainage work.

CONTACT: Ken Stone, Recycling Manager, Madison County, NY recycling center

REFERENCE: Personal communication from Andela Tool & Machine Co, of copy of article in the November 2, 1995, The Mid-York Weekly

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: The City of Gillette, WY is using cullet for daily cover at its landfill.

CONTACT: Karen Lawson, City of Gillette, WY (307)686-5280

REFERENCE: Telephone conversation, May 10, 1996

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: The Grand Canyon National Park is crushing the glass from its recycling program and using it for a variety of purposes, including landfill cover, traction on snow and ice and aggregate for trails.

CONTACT: Grand Canyon National Park, Arizona

REFERENCE: "Grand Canyon, Arizona. Recycled Glass finds Home in National Park", BioCycle, September 2001, page 19

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: Waste Management in Wisconsin is looking at using glass from its MRF in Madison for landfill cover.

CONTACT: Jerry Maerz, MRF Manager, 2418 W. Badger Road, Madison, WI 53713, (608)278-2363

REFERENCE: Personal discussion with Jerry Maerz, MRF Manager, Madison, WI, October 1, 2001

CATEGORY: Construction Aggregate
CLASS: Landfill Cover

DESCRIPTION: Austin, TX is processing 250-350 tons of glass a month for alternative uses, including as landfill cover and for aggregate on trails in their park system.

CONTACT: Katherine Murray, City of Austin Solid Waste Services, (512) 707-5474,
Katherine.Murray@ci.austin.tx.us

REFERENCE: Email from Katherine Murray, October 4, 2001

CATEGORY: Miscellaneous
CLASS: Landfill Gas Venting Systems

DESCRIPTION: Research at a landfill in Bavaria, Germany from December 1996 through October of 1998 has found that using glass as an aggregate in gas extraction systems provides treatment of the gas and removal of corrosive components.

CONTACT: Bayerischer Forschungsverbund Abfallverwertung und Reststoffverwertung (BayFORREST), Munich, Germany.

REFERENCE: Internet Web Page <http://www.deponieforschung.de/seite.php?navi=4|1|projekt|F102|1|en>, accessed July 1, 2003

CATEGORY: Construction Aggregate
CLASS: Landfill Gas Venting Systems

DESCRIPTION: In the State of New York, glass cullet has been used in several projects for the construction of gas venting systems at landfills. Under New York requirements, the gas-venting layer has to meet several specifications, including a minimum permeability of 1×10^{-3} centimeters per second and a maximum of 10% by weight passing the No. 200 sieve. The glass used by EMCON for several projects passed both of these specifications without any additional processing; as delivered from the MRFs, it had a permeability of 3×10^{-2} (and often, more than 1×10^{-1}), with less than 1% passing the No. 200 sieve.

In the gas venting system, a geotextile is placed on top of the glass layer to prevent cuts or puncture of the Flexible Membrane Liner which is placed on top of the glass layer. It is estimated that the glass provided a savings of approximately \$30,000 an acre.

CONTACT: Mark Swyka, EMCON, Mahwah, NJ

REFERENCE: "Alternative Construction Materials in Waste Containment Applications", Waste Age, March 1996, pages 114-116

CATEGORY: Construction Aggregate
CLASS: Landfill Leachate System Filter

DESCRIPTION: Processed glass from the Outagamie County, WI material recycling facility was tested in a laboratory for use as a leachate drainage media. Tests were done on the gradation, permeability, leachability of chemicals from the glass, and geomembrane compatibility. It was concluded that the glass was suitable from these aspects. However, it was also noted that the tests done were short term and that the permeability of the glass decreased by 73% versus 28% for pea gravel and that additional, longer-term, tests should be performed.

CONTACT: Gerald R. Eykholt, Civil and Environmental Engineering, University of Wisconsin-Madison, 1415 Engineering Drive, Madison, WI 53706, (608)263-3137

REFERENCE: Final Report. Use of Glass Aggregate as Leachate Drainage Media, Gerald R. Eykholt, University of Wisconsin-Madison, 158 pages, November 27, 1996. . Includes the report, The Use of Crushed, Recycled Glass as Drainage Media in Wisconsin Landfills, Judith Rose Steele, M.S. thesis, University of Wisconsin-Madison, 1996, 136 pages.

CATEGORY: Construction Aggregate
CLASS: Landfill Leachate System Filter

DESCRIPTION: In Connecticut, glass cullet was used as a component of the leachate collection system, acting as a filter. The glass was available in a crushed form from a demonstration project with the Connecticut Department of Transportation, and was found to be suitable for the use in the leachate collection system. It is estimated that the use of cullet saved about \$8,000 an acre.

CONTACT: Mark A. Swyka, EMCON, Mahwah, NJ

REFERENCE: "Alternative Construction Materials in Waste Containment Applications", Waste Age, March 1996, pages 114-116

CATEGORY: Construction Aggregate
CLASS: Landfill Leachate System Filter

DESCRIPTION: The Vancouver, BC Capital Regional District is using cullet as a filter media for the leachate collection system at its Hartland landfill.

CONTACT: Unknown

REFERENCE: Resource Recycling's Bottle/Can Recycling Update, August 1992, page 4

CATEGORY: Construction Aggregate
CLASS: Landfill Liner Cover

DESCRIPTION: A test was done of glass bottle cullet for a cover of a landfill liner system. Landfill liners need a cover to protect the liner from damage during the placement of waste. Commonly, fine aggregate is used for this purpose, and also serves in the collection of landfill leachate. It was decided to test glass cullet, both because of the need to develop alternative markets for mixed color and brown glass cullet, and because in Ohio, aggregate often has high levels of carbonate, which is not acceptable for liner cover material.

The cullet had to meet several standards of the State of Ohio, including a maximum amount of fines, a maximum amount of carbonates, and a minimum permeability. Processed and unprocessed cullet was tested both in the laboratory, and, after passing the criteria, it was also tested on an experimental plot, where it was laid down in a 12" thick layer and compacted using standard equipment.

It was concluded that the cullet was more than satisfactory in all accounts -- it had essentially no carbonates, the permeability was 500 to 2000 times the minimum standard, and the amount of fines was less than 2%. The cullet also caused minimal impact on the liner itself and was easy to work.

CONTACT: Bruce O. Schmucker, Browning-Ferris Industries of Ohio, Inc., or Rick J. Buffalini, Paul C. Rizzo Associates, Ohio

REFERENCE: "Pulverized Glass and Landfill Liner System", Waste Age, April 1995, pp 251-262

CATEGORY: Construction Aggregate
CLASS: Utility Trench Fill

DESCRIPTION: The State of Indiana has developed specifications for glass as utility trench bedding material, and the Indiana state environmental agency is promoting the recovery of glass into alternative uses.

CONTACT: Unknown

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Construction Aggregate
CLASS: Utility Trench Fill

DESCRIPTION: Abilene, Texas has been using pulverized glass in pipe bedding applications, golf course sand traps, where it is said to improve the drainage, for road base, and for sand filters.

CONTACT: The City of Abilene, Texas

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: A pilot plant is being established by Elizabeth City Glass to produce fused-glass products, including sandblasting abrasives, pavers, floor and wall tiles, concrete aggregate, drainage pipe, and filter media.

CONTACT: Shawn Lemmond, Elizabeth City Glass, North Carolina

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: The County of Maui in Hawaii has developed a number of alternatives to recycle glass, including its use as sandblasting material, in landscape decoration and as a 10% additive to base chords of roads.

CONTACT: County of Maui, Hawaii

REFERENCE: "From Hero to Bum in Less than a Heartbeat", Jack Beardwood, MSW Management, July/August 2002, pages 68-72

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: Tests are being done of crushed glass for sandblasting of ship hulls in San Diego. The crushed glass is being produced by a new type of crusher developed by Bosha-Silica of Idaho.

CONTACT: Bob Copeland, Bosha-Silica, 679 N. Five Mile, Boise, ID 83713, (208)376-0945

REFERENCE: Personal phone conversation with Bob Copeland, January 30, 1998

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: TriVistro Corporation in Seattle, WA has developed a 50 ton per day facility to make sandblasting material out of glass cullet. It is expected that the processed material may also be suitable for other uses, such as filtration media, paint additives, nonskid coatings, paving tiles and art glass.

CONTACT: Bob Kirby, CWC, (206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: "Custom Processor Opens New Glass Market", BioCycle, November 1996, page 24; Resource Recycling, July 1996, pages 129-130; Resource Recycling, May 1997, pages 60-63; "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: The Clean Washington Center is working on the use of glass cullet as blasting grit. As of March, 1995, they had had subjective trials done, are were negotiating for laboratory tests. So far, it

appears to work well for removing paint from steel and concrete. The expectation is that it may have a side beneficial effect regarding silicosis, since glass does not have free (crystalline) silica.

CONTACT: Bob Kirby, CWC, (206)389-2442 or(206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: The collector for the city of Telluride, Colorado, population 1,300, is processing mixed-color cullet from the municipal recycling program into three sizes for reuse as filtering material, sandblasting, and aquariums.

CONTACT: Burbridge Trash Service, Nucla, CO

REFERENCE: Resource Recycling, December 1994, page 42

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: Equipment has been produced to crush glass into "sand", which the equipment manufacturer claims can then be used for a variety of purposes, including golf course maintenance, sand blasting, concrete additives, water filtration, backfill drainage and aquarium aggregate. In 1994, they announced that they were building a factory to process glass for used in fiberglass, paint and golf course maintenance. In the summer of 1994, the company won a 2 year contract to supply its GlasSand product to the Edmonton plant of Fiberglas Canada.

CONTACT: Vitreous Environmental Group, Inc., maker of the GlassBlaster, PO Box 3202, Airdrie, Alberta, T4B 2B5 Canada, (403)948-7811

REFERENCE: BioCycle, December 1992, page 87; Recycling Today, September 1992, pages 30-31; literature from Vitreous Environmental Group, September 16, 1993, Resource Recycling, May 1994, page 77, Resource Recycling, September 1994, page 15

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: Image Analysis of Portland, Oregon interview potential markets for green cullet and found that the sandblasting market had the highest potential value (\$40 to \$60 a ton), with a moderate demand. In contrast, the building material market was termed as good, while the fill and landscaping markets were labeled as only fair.

CONTACT: Image Analysis, Portland, OR

REFERENCE: Resource Recycling's Bottle Can Recycling Update, July 1994, page 4

CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: An Ontario, New York firm, Hill Abrasives, began in June, 1991 to make extremely fine particle abrasives from bottle cullet. It is used both for sandblasting buildings as well as industrial

cleaning of products. It is said to do a superior job of cleaning with fewer worker health and environmental safety problems as compared to sand. It is also being used by Johnson Systems in Aurora, IL for water treatment systems.

CONTACT: John Hill, Hill Abrasives, Ontario, New York

REFERENCE: "Creating Local Jobs from Environmental Protection. Focus on Recycling and Small Business", March 1992, T. Paul Robbins, et. al, (city, organization unknown; received from Erv Sandlin, Texas Water Commission)

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CATEGORY: Industrial Mineral Use
CLASS: Sandblasting

DESCRIPTION: Marc Rudman, operator of West Paterson Automated Recycling in New Jersey, submitted a proposal to the New Jersey Department of Conservation to develop a market for glass abrasives. Glass may be a safer material than sand, since sand contributes to silicosis.

CONTACT: Marc Rudman, West Paterson Automated Recycling

REFERENCE: Resource Recycling, October 1991, page 72

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Prior to 1972, the Fullerton, CA Air Industrial Park used fiberglass insulation made from scrap glass.

CONTACT: unknown

REFERENCE: "Refuse Glass Aggregate in Portland Cement Concrete", J. C. Phillips and D. S. Cahn, Proceedings of the Third Mineral Waste Utilization Symposium, 1972, page 390

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Manville and other fiberglass insulation manufacturers are exploring the use of glass cullet to make fiberglass insulation. The two major concerns are quality (which are very stringent for fiberglass insulation) and the cost of the cullet.

CONTACT: Unknown

REFERENCE: Resource Recycling, June, 1990, pages 22-26

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: The potential use of cullet for the manufacture of fiberglass is described from the perspective of an employee of Owens-Corning. In a 1994 listing, it was stated that their fiberglass insulation uses 30% post-consumer glass.

CONTACT: Ernest Guter, Owens-Corning

REFERENCE: Glass Industry, January 1993, pages 13+ (taken from a 1991 speech); Harris Directory, The Stafford Architects, October 1994

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Schuller International has signed an agreement with Pure Tech International for Pure Tech to supply 20,000 tons of cullet for Schuller to use to make Manville-brand fiberglass insulation.

Schuller products bearing the Environment Canada EcoLogo contain at least 40% recycled glass content. Schuller says that it has recovered more than 100 million post-consumer glass bottles from Canada annually since 1986.

A 1994 listing said that Schuller uses a minimum of 20% recycled glass, including 15% post-consumer glass.

CONTACT: Valerie Brown, (800)786-7157 (April 1993)

REFERENCE: Resource Recycling, October 1992, page 90; Resource Recycling's Bottle/Can Recycling Update, April 1993, page 4; April 1995, page 106; Harris Directory, The Stafford Architects, October 1994

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Pure Tech International of Somerset, NJ has opened a 31,000 ton per year cullet processing plant in Bakersfield, CA to produce powdered glass for use by Schuller International.

CONTACT: Unknown

REFERENCE: Resource Recycling, January 1994, page 66

CATEGORY: Insulation Materials
CLASS: Fiberglass Insulation

DESCRIPTION: Fiberglass Canada hopes to use more than 90,000 tons of bottle cullet per year to make 50% recycled content fiberglass insulation.

CONTACT: Unknown

REFERENCE: Resource Recycling, June 1993, page 99

CATEGORY: Insulation Materials
CLASS: Fiberglass Insulation

DESCRIPTION: According to a survey commissioned by the North American Insulation Manufacturers Association, their members used 300,000 tons of recycled glass in 1992 to make fiberglass insulation, and had a projected 1993 use of over 350,000 tons. Quality remains the main issue for the use of cullet to make fiberglass insulation; the new standards established by the American Society of Testing and Materials are viewed as helping to expand the use of cullet at "a rapid clip".

CONTACT: Ken Mentzer, Executive Vice President, North American Insulation Manufacturers Association

REFERENCE: Glass Industry, October 1993, page 27

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Vitreous Environmental Group is building a glass container processing plant in Calgary, Alberta to produce material used for fiberglass, paint and golf course maintenance products. In the summer of 1994, the firm won a 2 year contract to produce material for Fiberglass Canada.

CONTACT: Vitreous Environmental Group, PO Box 3202, Airdrie, Alberta T4B 2B5, Canada (403)948-7811

REFERENCE: Resource Recycling, May 1994, page 77, September 1994, page 15

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: The Stafford Architects of Seattle, WA have prepared a directory of architectural products made with recycled material. The following companies are listed as using scrap glass to make fiberglass insulation, with the listed minimum percentages:

CertainTeed -- 20% post-consumer

Conglass and UPF -- 20% post-consumer

Schuller -- 20%, 15% post-consumer

Owens/Corning -- 30% post-consumer

CONTACT: B. J. Harris, The Stafford Architects, (206)682-4042

REFERENCE: Harris Directory, The Stafford Architects, October 1994

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: According to Joe Kaplan, manufacturing support engineer for Owens-Corning Fiberglass Corp., the use of cullet to make fiberglass is not likely to increase much during the next few years unless there are significant improvements in cullet quality at an affordable price. Owens-Corning currently uses about 300,000 tons of cullet a year, citing cost-control, environmental reasons and marketing reasons. Theoretically, 100% cullet could be used for fiberglass manufacture, but it is not currently available in the price and quality range that is needed by his firm.

CONTACT: Joe Kaplan, Owens-Corning Fiberglass Corp.

REFERENCE: Recycling Today, November 1995, pages 14-15

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: Strategic Materials, Inc. and Owens Corning are embarking on a test to better clean mixed color cullet for use in the manufacture of fiberglass insulation. During the test, Owens Corning plans to use 400 tons of this cullet a week. Owens currently uses about 400-800 tons of plate glass a week, but the supply of plate glass is declining, and Owens wants to increase its use of recycled material.

The biggest problem for increased utilization of cullet is the problem of contaminants. However, Owens has worked successfully with Canadian processors in 1995, and is encouraged by that success to pursue higher levels of recycling at its other plants.

CONTACT: Michael Burns, purchasing manager, Owens Corning, Toledo, Ohio

REFERENCE: Waste News, February 1996, page 15

CATEGORY: Insulation Applications
CLASS: Fiberglass Insulation

DESCRIPTION: In 1995, the fiberglass industry used 936.3 million pounds (468,000 tons) of recycled glass to make fiberglass insulation. This was the 3rd straight year of increase, with an estimate that over 1 billion pound would be used in 1996.

CONTACT: North American Insulation Manufacturers Association

REFERENCE: Glass Industry, January 1997, page 32

---CATEGORY: Insulation Applications

CLASS: Fiberglass Insulation

DESCRIPTION: Rumpke Recycling of Cincinnati, Ohio has worked with THECO LLC, a glass processor in Jackson Center, Ohio to produce a mixed cullet that is suitable for use in making fiberglass insulation. Critical factors include the quality of the cullet and the level of contamination, and providing a steady supply of cullet. Knauf, Inc., the fiberglass insulation manufacturer that that is using this cullet is looking to locate other manufacturing plants near sources of mixed cullet.

CONTACT: Benjamin Pedigo, Rumpke Recycling, Cincinnati, Ohio, (513)242-401

REFERENCE: "Exploring a Secondary Market for Mixed Cullet", Benjamin Pedigo, Resource Recycling, April 2000, pages 37-39

CATEGORY: Insulation Materials

CLASS: Foamglass Insulation

DESCRIPTION: A foamed glass product, made from cullet, water, calcium carbonate and bentonite, has been developed at the University of Utah. Commercial cullet can be used without cleaning, sizing or color sorting. Typical samples had thermal conductivity of around 0.4 BTU per hour/square foot/degree F per inch of thickness. The material has a density of 10 to 15 pounds per cubic foot and compressive strengths of 100-125 psi.

CONTACT: Unknown

REFERENCE: Glass Recycling and Reuse, Harold R. Samtur, University of Wisconsin-Madison Institute for Environmental Studies Report 17, March 1974, 100 pages; also see "Foamed Glass Insulation", A. Sosin, Albuquerque Symp. Util. Waste Glass Sec. Prod., 1973 and "Feasibility of Making Insulating Material by Foaming Waste Glass, H. Cahoon and I. Cutler, Proc. 3rd Min. Waste Util. Symp., March 1972

CATEGORY: Insulation Materials

CLASS: Foamglass Insulation

DESCRIPTION: A patent was granted in 1975 to the University of Utah for the manufacture of foam glass from waste glass, using an hydroxide group additive.

CONTACT: Patent 3,870,496

REFERENCE: Glass Technology. Recent Development, Noyes Data Corp., 1976, pages 37-38

CATEGORY: Insulation Materials

CLASS: Foamglass Insulation

DESCRIPTION: Crushed glass is heated with a foaming agent that releases small bubbles of gas. When the mixture cools, it becomes rigid and is a good insulation material. It can tolerate contamination and can use mixed colors.

CONTACT: Corning Corporation in Pittsburgh is the only company that currently produces this material.

REFERENCE: The Minnesota Project, July 1992; "Waste Glass Container Markets in the Wisconsin Region. Executive Summary", Resource Management Associates, Napa, CA, July 1992, page VI-24; and Resource Recycling, October 1991, pages 73-74

CATEGORY: Insulation Materials
CLASS: Foamglass Insulation

DESCRIPTION: A patent was granted in 1974 to the University of California to make foam glass using a combination of waste glass and human or animal excreta.

CONTACT: Patent 3,811,851

REFERENCE: Glass Technology. Recent Development, Noyes Data Corp., 1976, pages 37-38

CATEGORY: Insulation Applications
CLASS: Foamglass Insulation

DESCRIPTION: A Massachusetts firm known as Recycled Glass Products is working on a foamed insulation from recycled glass to make structural wall panels. Called ReFormedGlas, the product has been tested to determine its insulation value. However, commercial production has not yet been done. Financing is still being sought, and designs are being done for a furnace and manufacturing system. (Note: This firm was previously in Rhode Island.)

CONTACT: David Solomon, President, Recycled Glass Products, Inc., Jamaica Plain, Massachusetts, (617)522-9695

REFERENCE: Personal correspondence from Marty Davey, Rhode Island DEM, January 24, 1996; Resource Recycling, July 1996, page 129; "Entrepreneurs Surf the Waste Stream", BioCycle, November 1996, page 36

CATEGORY: Paving Applications
CLASS: Aggregate

DESCRIPTION: The French firm ESPORTEC – which focuses on soil stabilization -- has developed a stabilization product out of recycled container and flat glass. The material can be used for walking, biking and similar pathways, as well as plazas and parking lots. The glass is reduced in size, chemically activated and mixed with binding materials.

CONTACT: ESPORTEC, web page <http://esportec.chez.tiscali.fr/>. Site is in French only.

REFERENCE: “Frankreich; Glaszement zum Stabilisieren von Wegen [France: Glass Cement for Stabilizing of Pathways]”, web page <http://www.recyclingmagazin.de/nachrichten/detail.asp?PAGE=3&ID=280>, and the web page of ESPORTEC, <http://esportec.chez.tiscali.fr/>, both accessed on July 17, 2003

CATEGORY: Paving Applications
CLASS: Aggregate

DESCRIPTION: Austin, TX is processing 250-350 tons of glass a month for alternative uses, including as landfill cover and for aggregate on trails in their park system.

CONTACT: Katherine Murray, City of Austin Solid Waste Services, (512) 707-5474,
Katherine.Murray@ci.austin.tx.us

REFERENCE: Email from Katherine Murray, October 4, 2001

CATEGORY: Paving Applications
CLASS: Aggregate

DESCRIPTION: The Grand Canyon National Park is crushing up the glass from its recycling program and using it for a variety of purposes, including aggregate on hiking trails and in roads, for bedding around plumbing, for landfill cover and for traction on snow and ice.

CONTACT: Grand Canyon, Arizona

REFERENCE: “Grand Canyon, Arizona. Recycled Glass finds Home in National Park”, BioCycle, September 2001, page 19

CATEGORY: Paving Applications
CLASS: Aggregate

DESCRIPTION: The City of Portland, Oregon used crushed green bottle cullet to create a 3,600 foot long recreation trail called "The Emerald Path".

CONTACT: Unknown

REFERENCE: Resource Recycling, October 1993, page 83

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Ocean County, New Jersey, has used processed glass for road construction for both the top coat and the base for more than 10 years. Interest in glasphalt has surged in recent years.

CONTACT: John Haas, County Recycling Coordinator, Ocean County, NJ

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The Delaware Solid Waste Authority (DSWA) is using 10% crushed glass and 90% other aggregates for making asphalt.

CONTACT: <http://www.dswa.com>

REFERENCE: "Business Briefs. Update. Delaware Crushes Glass Recycling Problem", Waste Age, February 2002, page 18

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The state of Iowa natural resources and transportation agencies have funded six pilot projects to use processed glass in asphalt, including parking lots and recreational trails.

CONTACT: Not given

REFERENCE: "Glass", Resource Recycling, January 2002, page 37

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The City of Cambridge, MA used glasphalt in a pathway in a city park that was built on top of a closed landfill.

CONTACT: Rich Rossi, Deputy City Manager, City of Cambridge, MA

REFERENCE: "A Landfill's Second Career Proves Successful", Kim A. O'Connell, Waste Age, December 1999, pages 7-8

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The City of Allentown, Pennsylvania has used more than 80,000 tons of glasphalt to pave more than 70 streets since 1993, according to Neal Kern, the Director of Public Works and City Engineer. It also plans to use 40,000 tons in 1997.

CONTACT: City of Allentown, PA Department of Public Works

REFERENCE: "Pennsylvania Mixed Glass Roundtable Places Focus on Local Level, New Markets", Bethany Barber, Recycling Times, July 7, 1997

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Baltimore, MD, used glass cullet in asphalt from 1971 to 1988, and used the material on 20 different projects. It discontinued its use because it was not cost competitive.

CONTACT: Paul Turner, Bureau of Transportation, Department of Public Works, 417 E. Fayette Street, Baltimore, MD 21202, (410)396-6861

REFERENCE: Personal communication from Elissa Ditrio, Recycling Services Division, Maryland Department of the Environment, 2500 Broening Highway, Baltimore, MD 21224, (410)631-3000, January 29, 1996

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Frederick County, MD paved a 20,000 square foot area at its recycling center with glasphalt containing 30% by weight cullet. A four inch base of asphalt was used, topped with 2 inches of glasphalt, because there wasn't enough glass to add glass to the entire 6 inches of material.

CONTACT: Phil Bresee, Frederick County Department of Public Works, 9031 Reich's Ford Road, Frederick, MD 21704, (301)694-1848

REFERENCE: Personal communication from Elissa Ditrio, Recycling Services Division, Maryland Department of the Environment, 2500 Broening Highway, Baltimore, MD 21224, (410)631-3000, January 29, 1996

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In Ohio, the Ottawa Seneca Sandusky Solid Waste Management District has used 45 tons of cullet as an additive to asphalt for the paving of a 1-mile length of road. The cullet was provided by the Ensely Corporation of North Canton, Ohio.

CONTACT: Unknown

REFERENCE: Recycling Today, January 1996, page 18

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In Ohio, Hamilton County paved a mile or so of downtown Cincinnati with glasphalt, using locally obtained cullet.

CONTACT: Karen Luken, Solid Waste Program Manager, Hamilton County Solid Waste District, (513)333-4719

REFERENCE: Internet message from George Peters, Ohio Division of Recycling and Litter Prevention, January 16, 1996

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Outagamie County, Wisconsin is testing the use of glass in asphalt, both for asphalt patch material as well as for glasphalt. So far, they have been using both the brown and green glass

(for which the market price is low) and the mixed color cullet as patch material. Patch material is formed at a lower temperature (180 degrees) versus regular paving asphalt (300 degrees). The glass is crushed to the same size as the gravel it is replacing, and tests are being done on two mix designs. While normally, 1,800 pounds of gravel are added to 200 pounds of asphalt, Outagamie County is testing one mix of 600 pounds of glass with 1,200 pounds of gravel, and another of 1,900 pounds of glass and only 100 pounds of asphalt. It is believed that the glass will absorb less asphalt than gravel and than therefore a larger aggregate-asphalt ratio can be used with glass than with stone. The test material is also being used by the City of Appleton and the Town of Grand Chute. In the initial test, done in September 1994, 362 tons of patch material were produced using 33% glass and 67% stone. Asphalt (HFE-1000) was added at the amount of 7.2%. A 75 foot patch as applied to a road that has an average of 600 vehicles per day with a 55 mile an hour speed limit. The operator noticed no difference in applying glass aggregate patch material versus stone aggregate patch material. No stripping of the glass was visible after two weeks. Work is still proceeding on other test plots, and a total of patch material will be utilized, with application during both cold and warm weather. To date, the conclusions are:

- use an anti-stripping agent
- use a maximum of 25% glass
- glass should 100% pass a 3/8" sieve and 8% maximum pass #200 sieve
- maintain a tensile stress ration of 90%
- limit the use to low speed and low volume roads

One of the project's conclusions is that the use of glasphalt for patch material would not use a sufficiently large amount of glass, and therefore, in early 1995, the County received additional funding to test the use of glass for normal pavement material.

The use of cullet is glasphalt is to be done in 1995, with the results to be published in 1996. The plan is to replace 30% of the aggregate with glass, utilizing an estimated 60 pounds of mixed glass for every square yard of asphalt.

The Highway Commissioner for Outagamie County, Mike Marsden, does not believe that the use of glass as a substitute for gravel in regular pavement will ever be suitable as there is an insufficient supply of glass for this purpose.

CONTACT: Mike Marsden, Outagamie County Highway Department, Appleton, WI

REFERENCE: Articles from the Appleton Post Crescent, November 6, 1993 and November 7, 1994 and grant application to Wisconsin DNR, January 22, 1994; January 31, 1995 grant application to WI DNR; Presentation by Sue Rundquist, Outagamie County Recycling Coordinator to AROW recycling conference, March 7, 1995; and telephone conversation with Rich Braddock, DNR recycling markets specialist, May 3, 1995

CATEGORY: Paving Applications

CLASS: Asphalt (Glasphalt)

DESCRIPTION: According to a chart of uses of waste products in new asphalt, 2.4 million metric tons of glass have been used to make glasphalt in the US. The source of the data is given as the US Department of Transportation.

CONTACT: Unknown contact at US DOT

REFERENCE: Recycling Today, November 1995, page 74

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Broome County, NY is exploring the use of glasphalt. The State of New York Department of Transportation has allowed up to 30% cullet in asphalt.

CONTACT: Lisa Rosa, Material Recovery Manager, Broome County, NY

REFERENCE: Reprint from Waste Handling Equipment News, no date, provided by Andela Tool & Machine Inc., fall 1995

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Brooklyn, NY is processing cullet from a local recycling program (Hunts Point Recycling) to use in glasphalt, using 10% cullet (100 tons a day) in the top coat of the asphalt. They have been using cullet in asphalt for over 6 years, and from Hunts Point since mid-1994.

CONTACT: Mike Mongelli, Operation Manager, Hunts Point Recycling, New York, NY

REFERENCE: Reprint from Waste Handling Equipment News, no date, provided by Andela Tool & Machine Inc., fall 1995

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The State of Pennsylvania has been working with its paving contractors to use glass as an aggregate in asphalt. The goal was to use 100,000 tons of glass cullet in asphalt and other uses in 1992.

In 1995, PA Department of Transportation officials removed the specification for the use of glasphalt in the wearing course of pavement, saying that it performed poorly. Glasphalt would be allowed in the other layers of pavement, however. Local officials believe that the state did not adequately study the use of glasphalt in the wearing course, and, since it is the wearing course of the pavement that is replaced most frequently, the DOT decision will significantly reduce the market opportunities for glasphalt.

CONTACT: Meridith Hill, Office of Air and Waste Management, PA Dept of Environmental Resources, (717)772-2724

REFERENCE: PenCycle BBS, March 19, 1992; Resource Recycling, June 1992, page 70; Recycling Times, May 30, 1995, page 16

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Palm Beach County, Florida did a pilot project glasphalt project in September 1992. As of February 1995, they were using mixed color cullet from their MRF for glasphalt.

CONTACT: Jana Haskins or Scott Riemer, 7501 North Jog Road, West Palm Beach, FL 33412, (407)471-2700

REFERENCE: V. David Baker, Southeast Glass Recycling Program, Clearwater, FL, winter 1992-93 and personal telephone conversation with Scott Riemer, The Solid Waste Authority of Palm Beach County, FL, February 13, 1995

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: This handbook is intended to be used by those involved in either paving or recycling, and describes how to prepare, install and use glasphalt. Information is provided on known uses of glasphalt in North America, specifications and technical results. Research on glasphalt for over 20 years has shown that it can meet all the technical requirements of the Asphalt Institute. Glasphalt can be used for either base course or surface course, but when used as a surface course, the authors recommend that it be limited to pavement which has operating speeds of less than 40 miles per hour. Also, as a surface course aggregate, the glass should be 3/8" or preferably 1/4" or less, and limited to a maximum of 20% of the rock aggregate. The only differences between normal asphalt and glasphalt are: (1) glasphalt tends to retain heat longer, (2) when the glass is exposed, it can produce a (pleasing) glitter from sunlight or headlights, and (3) it dries quicker after precipitation. The economics of using glasphalt will depend on local situations for recycling, landfilling, and the cost of conventional asphalt paving.

CONTACT: Delbert Day, University of Missouri-Rolla, School of Mines and Metallurgy, Rolla, MO 65401-0249, (314)341-4354

REFERENCE: Glasphalt Paving Handbook, Delbert Day and Robert Schaffer, University of Missouri-Rolla, c. 1994, 53 pages

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Jones Quarry in Olympia, Washington has installed a 300 ton per hour (55 ton per hour) crusher to produce cullet aggregate for asphalt. One of the first projects was the construction of a tennis court at the home of the owner of the quarry. Other projects were underway in the summer of 1994.

CONTACT: Jones Quarry, Olympia, Washington

REFERENCE: Resource Recycling, October 1993, page 83, BioCycle, August 1994, pp 37-38

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In early 1994, the Oneida-Herkimer, NY solid waste authority was testing a machine to pulverize mixed color glass to use as an additive for asphalt paving projects.

CONTACT: (315)733-1224

REFERENCE: Bottle/Can Recycling Update, March 1994, page 5

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In England, the glass trade association, British Glass, helped to fund some work on the use of glass cullet in asphalt. Trial blocks were made and tested at the Road Research Laboratories. The blocks showed that good wearing and non-slip surfaces could be produced, although no economic advantages could be identified. Following these tests, a section of road of glasphalt was laid in the City of Westminster, using 17% cullet. The date of the construction and the results were not presented in the article.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256-258

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Laboratory tests were done to determine the uniaxial tension and compression properties of an asphaltic concrete composed of scrap tires, crushed beer bottles and asphalt. Besides presenting the results, the researchers concluded that the use of these materials would be to decrease thermal distress in the pavement due to the glass and increased elongation or strain due to the rubber. They recommended further tests varying the characteristics of the mixtures to optimize the mixture.

CONTACT: Unknown

REFERENCE: "Scrap Tire-Beer Bottle Concrete", Materiaux Et Constructions, Volume 5, No. 27, pages 151-157

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Goodwill Industries of Lane County, OR has a demonstration project using glasphalt in the drive-thru lane of their dropoff center for reusable items. The glass was mixed cullet.

CONTACT: Nancy Glines, Goodwill Industries of Lane County, 855 Seneca Road, Eugene, OR 97402, (503)345-1801

REFERENCE: Association of Oregon Recyclers, January 23, 1993

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Douglas County, Oregon has done a demonstration project using glasphalt to resurface approximately 1 mile of road near Wilbur, OR.

CONTACT: Aaron Cubic, Douglas County, Courthouse, Room 220, Roseburg, OR 97470, (503)440-4350

REFERENCE: Association of Oregon Recyclers, January 23, 1993

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The Florida Department of Transportation (DOT) did laboratory testing of asphalt with glass aggregate, with one mixture having 15% coarse aggregate (97% less than 3/8", and 86% greater than No. 10 sieve) and another with fine aggregate (85% less than No. 10 sieve). The tests showed a loss in tensile strength of 12-23% for the unconditioned samples. In tests of the

samples conditioned with water, the coarse aggregate samples had a smaller loss of strength than the control, while the samples with small particle size were much more adversely affected. The use of antistripping agents had little effect on tensile strength in any of the tests, although the antistripping agents did substantially reduce the amount of glass stripped from the asphalt. The authors cautiously concluded that glass could be used as an asphalt aggregate in some circumstances. They recommend that glass in asphalt not exceed 15%, with 100% passing a 3/8" sieve, and no more than 8% passing the No. 200 sieve.

CONTACT: Florida DOT, PO Box 1029, Gainesville, FL 32602

REFERENCE: "Evaluation of Crushed Glass in Asphalt Paving Mixtures", Kenneth Murphy, et. al., State of Florida Department of Transportation, April, 1991, 14 pages, "Evaluation of Crushed Glass in Asphalt Paving Materials", Randy C. West, et. al., Use of Waste Materials in Hot-Mix Asphalt, ASTM STP 1193, American Society of Testing Materials, Philadelphia, 1993, pages 117-125

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Just east of Rolla, MO, 22 tons of glass were used to pave 200 feet of roadway on Highway V and I-44 in September, 1992.

CONTACT: Dennis Roedemeier, Executive Director, Missouri Enterprise, University of Missouri-Rolla

REFERENCE: Recycling Times, April 6, 1993, page 6

---CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In a 1993 book which is based on a 1991 study done for the US Department of Transportation and other agencies, the use of glass cullet as a highway construction material is reviewed, along with providing recommendations.

A 1989 Connecticut report found that glasphalt had been used in at least 45 US locations from 1969 to 1988, with the majority on city streets, driveways and parking lots, and not on high-volume, high-speed highways. Maximum cullet size is given as 3/8", with hydrated lime added to prevent stripping, and should be used only as a base course to prevent potential problems with skid resistance and surface raveling.

A 1990 Virginia report tested cullet at 5% and 15% levels, and found that the resilient modulus and tensile strengths of the pavement were not adversely affected, and that although wet strength and tensile strength ratio moisture damage values were unaffected, there was some separation at the asphalt/glass interface. Finally, the glass tends to reduce the voids in mineral aggregate (VMA) and voids in total mix (VTM), and increase voids filled with asphalt (VFA) from Marshall-compacted specimens. The Virginia study concluded that the use of cullet was feasible if the following conditions were observed:

- glass content a maximum of 15%
- the optimum asphalt content must be determined with the target percent of glass to be used
- 100% pass a 3/8" sieve and a maximum of 6% passing a No. 200 sieve
- TSR of the mix of at least 0.9
- there is little monetary incentive to use cullet at the time of the study

The author of this book concludes that several areas of research are still needed to address potential problems with the use of cullet in asphalt:

- the effect of moisture on glasphalt
- type and quantity of the most suitable antistripping agent
- the maximum amount of glass, and the most appropriate gradation
- optimum asphalt content and evaluation procedure for the asphalt
- maintenance of skid resistance

CONTACT: Imtiaz Ahmed, Purdue University, West Lafayette, Indiana

REFERENCE: Use of Waste Materials in Highway Construction, Imtiaz Ahmed, Noyes Data Corporation, 1993, pp 45-55, 85-86, 92

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Waste glass was tested in laboratory and field tests in the early 1970's, after which there was no significant interest for a decade. Now, the potential to use glass in asphalt has had a rekindling of interest, with research projects and reports from three states -- Connecticut, Virginia, and Florida.

The Connecticut report gives an excellent review of the literature on both laboratory and field studies since 1969 and concludes the following:

- Glasphalt was successfully used in at least 45 projects in the US and Canada between 1969 and 1988, with most projects being city streets, driveways and parking lots, and not high-volume, high-speed highways
- Potential problems with glasphalt include:
 - loss of adhesion between asphalt and glass
 - maintenance of an adequate level of skid resistance, especially with coarse particles
 - breakage of glass and subsequent raveling under studded tires
 - lack of adequate and consistent supply of glass
 - increased products costs, estimated at \$5/Mg
- Glasphalt should be used only as a base course to alleviate potential skid resistance and surface raveling problems
- A maximum size of 9.5 mm [3/8"] cullet should be used, with hydrated lime to prevent stripping.

The Virginia report is both a laboratory analysis and an economic evaluation, using 5 and 15% cullet and two asphalt contents. The cullet was a maximum nominal size of 9.5 mm [3/8"]. The evaluation was of an S-5 surface HMA. Conclusion were:

- Glass tends to reduce the VMA and air voids in Marshall specimens; therefore, optimum asphalt content will also be reduced.
- Neither the resilient modulus nor indirect tensile strengths are adversely affected by the addition of up to 15% glass.
- Although both wet strength and retained tensile strength ratios (TSR) were unaffected by the percentage of glass, some separation at the asphalt/glass interface was observed.
- A maximum of 15% crushed glass should be allow, with 100% passing a 9.5 mm sieve and a maximum of 6% passing a 75 μ m sieve.

- There is little monetary incentive to use cullet because the cost of cullet varies considerably.
- An experimental section should be laid prior to extensive use of cullet.

The Florida research tested 3 HMA mixtures:

- control (9.5 mm maximum size)
- 15% coarse glass; same as the control except that 15% of the screenings were replaced with coarse (9.5 to 2.06 mm nominal size) crushed glass
- 15% fine glass; same as the control, except that 15% of the screenings were replaced with fine (2.06 mm - 75 μ m nominal size) crushed glass

AC-30 asphalt cement, both with and without an antistripping agent, was used to prepare Marshall specimens, and also tested for tensile strength, with the following conclusions:

- Marshall stability values decreased by 15-20% and dry indirect tensile strength decreased by 20% when 15% of the screenings were replaced by either the coarse or the fine glass.
- Moisture conditioning of Marshall specimens caused a 15% and 50% decrease in tensile strength for the coarse and fine glass replacements, respectively. Retained tensile strength ratio values indicated that the antistripping agent was ineffective in reducing the moisture damage.
- It is unlikely that the use of crushed glass in HMA will be economically feasible if suitable materials are available near the HMA facility.

In addition to these three reports, a survey of the states found that 7 were testing glass cullet as aggregate in hot mix asphalt concrete (HMAC), and 6 states were actually using cullet in HMAC, while 5 states had developed specifications for the use of glass in HMAC.

CONTACT: ASTM, 1916 Race Street, Philadelphia, PA 19103

REFERENCE: Use of Waste Materials in Hot-Mix Asphalt, H. Fred Waller, editor, STP 1193, 1993, ASTM, "Waste Materials in Hot-Mix Asphalt -- An Overview", Prithvi S. Kandhal, pp 3-16, "Current Nationwide Status of the Use of Waste Materials in Hot-Mix Asphalt Mixtures and Pavements", Stanley K. Ciesielski and Robert J. Collins, pp 17-36, "Evaluation of Crushed Glass in Asphalt Paving Mixtures", Randy C. West, et. al., pp 117-125

 CATEGORY: Paving Applications
 CLASS: Asphalt (Glasphalt)

DESCRIPTION: In a 1993 report to Congress, the Federal Highway Administration reported that at least 10 states had used cullet in asphalt, and the report concludes that this practice is successful if the following conditions are followed:

1. The amount of glass is limited to 15% of total aggregate.
2. The glass is crushed to 100% passage of 3/8" screen, and no more than 8 percent pass a No. 200 sieve.
3. An anti-strip additive is added to improve resistance to moisture damage.
4. HMA with cullet is limited to binder or base course and is not

used in a surface or friction course.

On the health and environmental impacts, the report says that no studies have been done for the use of cullet in glasphalt, but that stack emissions and leachate should not be a problem due to the inert nature of cullet. Economically, the report states "Its use may not be cost-effective nor may it impart any beneficial attributes to a pavement other than reflectivity."

In a summary of all potential uses of glass cullet for highway construction, the report concludes that "The quantity of glass is relatively small with respect to potential uses in the highway network."

CONTACT: Unknown

REFERENCE: A Study of the Use of Recycled Paving Material. Report to Congress. June 1993, Federal Highway Administration, US Department of Transportation, FHWA-RD-93-147, EPA/600/R-93/095, 34 pages; Appendix 1. Engineering and Environmental Aspects of Recycled Materials for Highway Construction. Final Report, US EPA and US DOT, FHWA-RD-93-088, June 1993, 212 pages

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: As of early 1993, the Department of Transportation of 9 states use glass in road pavement, apparently all for use as glasphalt. A report on the use of waste materials in highway construction is due later in 1993 from the Transportation Research Board (TRB).

CONTACT: Robert Collins, R. J. Collins & Associates, Springfield, PA

REFERENCE: Civil Engineering, April 1993, pages 46-49

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Maryland's Department of the Environment Recycling Division is conducting a study on the use of mixed glass in the production of glasphalt.

CONTACT: Glenn Dodson, (410)631-3315

REFERENCE: NRC Market Development News Link, Summer 1993, page 4

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: King County, WA tested the use of glasphalt, first in the laboratory and then in a test of 4 different mixtures. While the glasphalt did not meet all the standard test specifications, missing some by a few percentage points, the test pavements were in excellent shape and met skid resistance criteria almost a year later.

CONTACT: King County, WA Commission for Marketing Recyclable Materials, (206)296-4439

REFERENCE: "Technology Brief. King County Glassphalt Demonstration Project", Clean Washington Center, June 1993, 2 pages.

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In Wisconsin, Payne and Dolan, a large asphalt company, is experimenting with using glasphalt in their parking lot in Waukesha.

CONTACT: Butch Benish, Payne and Dolan, Waukesha, WI, (414)524-1753 or Gerald Waelti, Wisconsin Asphalt Pavement Association, 122 State Street, Madison, WI 53703, (608)255-3114

REFERENCE: APWA Wisconsin Chapter News, July 1993, page 3

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Rosetto Recycling Center in Toms River, NJ, has used glasphalt to pave its parking lot.

CONTACT: Bruce Rosetto, (201)796-7788.

REFERENCE: Article from the Ocean County (NJ) Reporter, January 7, 1993

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Sibley County, Minnesota has used approximately 330 tons of contaminated cullet as a road aggregate under asphalt. In June, 1992, a 1000 foot test section was built by laying down three lifts of 3" of 10% glass and 90% gravel, topped by a 4" layer of 100% aggregate and then 3" of bituminous pavement.

CONTACT: Gene Isakson, Director of Public Works, Sibley County, MN, (612)237-2403

REFERENCE: Undated newspaper stories and fact sheets; June 17, 1992 MN Department of Transportation news release. There is also a 1992 report to the Minnesota Office of Waste Management by Sibley County Public Works, William Mueller & Sons and the Minnesota Department of Transportation

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Boone County, Indiana was planning a demonstration project to use a variety of recyclable materials in road construction, including glass as aggregate in asphalt. The glass would be 99.6% smaller than 3/8", 56% smaller than a No. 8 sieve, and 19.4% smaller than a No. 30 sieve.

CONTACT: Boone County, IN, or Heritage Research Group, 7901 W. Morris Street, Indianapolis, IN 46231, (317)243-0811

REFERENCE: "Demonstration Project for Utilizing Crumb Rubber, Glass, and Plastics in Cold Mix Asphalt", Heritage Research Group, Indianapolis, IN, September 11, 1992, 8 pages

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Several demonstration projects are underway in Hawaii (Maui County, Kauai County, City and County of Honolulu) to use crushed cullet in glasphalt. The Hawaii Legislature has enacted a

law (Act 213-92) that requires the use of glass in glasphalt and as an aggregate in non-structural applications.

CONTACT: John Harder, Office of Solid Waste Management, 5 Waterfront Plaza, 500 Ala Moana Blvd, Honolulu, HI 96813

REFERENCE: Same, winter 1992-93

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: New York City is using cullet crushed to 3/8" to make glasphalt used for nearly 1/3 of all of the city's street maintenance projects for both surface and binder layers. The city has been able to use up to 30% cullet. The city says that the glasphalt pavements have performed "as well as, if not better than, conventional pavements." The city does not use any additives to prevent stripping.

CONTACT: Bill Slater, Quality Control Manager, New York City asphalt plant.

REFERENCE: Resource Recycling, November 1992, page 39; Waste Age, November 1992, page 92

CATEGORY: Paving Application
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The City of Menasha, WI is has used crushed glass bottles to make glasphalt, replacing about 10% of the aggregate with glass. They did not have good results the first time they tried to do this, as the labels on the glass bottles and jars jammed the crushing machine, preventing the glass from being broken up into small enough pieces to be usable. They solved this problem by crushing the glass in combination with the other aggregate. In the fall of 1992, the City laid a test block of pavement, using 7.5% glass crushed to 3/8" minus, with 6.1% asphalt, using an anti-stripping agent. As of May, 1993, they have not had any stripping or skid problems. The pavement has a noticeable reflectivity, which has proven to be advantageous.

CONTACT: Mark Radtke, Director of Public Works, 140 Main Street, Menasha, WI 54952

REFERENCE: Appleton Post-Crescent newspaper, October 31, 1992 and letter from Mark Radtke, May 12, 1993.

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Los Angeles is embarking on a major program to use glass cullet in the production of asphalt, using 10% by weight of cullet in the finished product, for a total of 50,000 tons per year. Based on their research, they have found that it better to crush the glass to a smaller size than normal aggregate; their specification calls for the glass to be sand size (No. 8 sieve). Tests were also done for health and safety tests of workers using the glass aggregate; exposures were well below OSHA standards.

CONTACT: Gregory Scott, Los Angeles Bureau of Street Maintenance, 200 N. Main St., Room 1545, Los Angeles, CA 90012, (213)485-3427

REFERENCE: Solid Waste Technologies, November/December, 1993, pages 40-45

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: A private firm, Gallagher & Burk, Inc., used three color cullet to build its asphalt concrete parking lot in the Bay Area of California. In 1992, they planned to use 54,000 tons of cullet in their asphalt mixes, setting up a glass crusher at their quarry in Oakland.

CONTACT: Unknown

REFERENCE: "Market Status Report. Glass", California Integrated Waste Management Board, July 23, 1992, page 29

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Norwalk, CT and other communities in Connecticut have been trying the use of cullet in asphalt. While Norwalk laid 3,500 feet of glasphalt in 1989 and planned to use 3,000 tons of glasphalt in 1992, the State of Connecticut has not formally approved the use of glass cullet in asphalt due to the lack of long-term testing of glasphalt. The glasphalt seems to perform about the same as normal asphalt, although there is somewhat lower skid resistance (but still within requirements); here's additional glare or sparkle; and some additional stripping of the aggregate, especially in newly-laid pavement. To reduce stripping, hydrated lime is added to glasphalt.

CONTACT: Dominick Di Gangi, Public Works Director, Norwalk, CT

REFERENCE: Waste Age, November 1992, pages 87-92

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The California Department of Transportation was scheduled to do a glasphalt pilot project in 1992.

CONTACT: Unknown

REFERENCE: "Market Status Report. Glass", California Integrated Waste Management Board, July 23, 1992, page 29

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The City of Los Angeles has tested a microwave process to recycle glasphalt and found that it worked well.

CONTACT: Unknown

REFERENCE: "Market Status Report. Glass", California Integrated Waste Management Board, July 23, 1992, page 29

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: A private firm in Albany, NY has been using 500 to 1,000 tons of container and window cullet to make glasphalt.

CONTACT: King Road Materials, Albany, NY

REFERENCE: Resource Recycling, October 1991, pages 86-87

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The City of Syracuse, NY is using about 2,000 tons of off-specification cullet annually from a local recycling processor for glasphalt.

CONTACT: Unknown

REFERENCE: Resource Recycling, October 1991, page 87; and "Best Practices" in The Market, July 1991, a newsletter of the New York State Office of Recycling Market Development

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The State of New Jersey Department of Transportation has specifications which allow the use of glass cullet in asphalt.

CONTACT: Unknown

REFERENCE: Resource Recycling, October 1991, page 72

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The state of Connecticut Department of Transportation did a survey of the potential to use waste glass in pavement. They concluded that waste glass is not suitable in portland cement concrete due to the alkali-silica reaction, and listed 23 projects (out of at least 45 such projects in the US and Canada) where glass had been used in asphalt concrete. They felt that more long-term studies needed to be done on a number of topics including skid resistance, and recommended that further study also be done on other highway uses, such as embankments.

CONTACT: State of Connecticut Department of Transportation, Wocott Hil Road, PO Drawer A, Wethersfield, CT 06109

REFERENCE: Feasibility of Utilizing Waste Glass in Pavements, CT DOT, June 1989, 27 pages, Report 343-21-89-6

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Baltimore, MD, New York City and Long Island, NY have used glass cullet to make glasphalt. Baltimore has used cullet since 1971 in sizes of up to 3/4", and up to 30% to 40% cullet. On Long Island, the optimum size is said to be 5/16", while New York City specifications are for 3/8" or less.

CONTACT: Unknown

REFERENCE: Resource Recycling, July 1988, pages 18-21

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: In 1972, the Royal Oak Beautification Council of Royal Oak, MI paved a 1.2 acre parking lot with a 1.5 inch bituminous binder containing crushed glass and used concrete, topped by a 1 inch wearing surface that did not contain the used concrete. The glass and concrete mixture had never been used before outside of the laboratory. The mixture was put together by Allied Chemical's Barrett Paving Materials Department. The base course contained 25% each of glass and concrete crushed to minus 3/8", 44% minus 3/4" stone aggregate, 5.5% asphalt, and 1% hydrated lime. The top course was 50% glass, 43% sand, 6% asphalt and 1% lime. The concrete and glass were crushed and processed by Gale Crushed Concrete & Aggregate, Inc.

CONTACT: unknown

REFERENCE: "Pavement is Half Glass and Concrete Waste", Engineering News Record, October 26, 1972

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: Prior to 1972, the Fullerton, CA Air Industrial Park used glasphalt to pave a road.

CONTACT: unknown

REFERENCE: "Refuse Glass Aggregate in Portland Cement Concrete", J. C. Phillips and D. S. Cahn, Proceedings of the Third Mineral Waste Utilization Symposium, 1972, page 390

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The effect of contamination in recycled glass used for glasphalt was studied at the University of Missouri-Rolla, which did the original work on glasphalt. The major impact seemed to be an increase in the void spaces in the pavement, with a resultant loss of pavement stability. Alteration of the gradation of the aggregate, increasing the asphalt content, and reducing the amount of waste glass all helped to reduce the impact of contamination.

CONTACT: Unknown

REFERENCE: "Effect of Contaminants in Recycled Glass Utilized for Glasphalt", W. R. Malisch, et. al., Proceedings of the Third Mineral Waste Utilization Symposium, 1972, pages 372-384

CATEGORY: Paving Applications
CLASS: Asphalt (Glasphalt)

DESCRIPTION: The earliest known research projects on the use of glass in asphalt was done at the University of Missouri-Rolla and this article reports on some of their earliest results. The aggregate was produced from washed bottles, ground to less than 1/2", with 48% less than a No. 8 sieve. This aggregate was combined with 5.5% asphalt and used both for patching pavement as well as to install a strip of glasphalt at the Owens- Illinois, Inc. technical center in Toledo, Ohio.

CONTACT: Unknown

REFERENCE: "Use of Waste Glass for Urban Paving", Ward Malisch, et. al., Proceedings of the Second Mineral Waste Utilization Symposium, March 18-19, 1970, pages 369-373

CATEGORY: Paving Applications
CLASS: Concrete

DESCRIPTION: A private firm in the state of New York has obtained a \$200,000 grant to develop a way to employ a glass powder in making a lightweight concrete product. The grant is from the state's Environmental Investment Program.

CONTACT: Buffalo Materials Technology, Hamburg, NY

REFERENCE: "Glass", Resource Recycling, April 2003, page 38; web page
http://www.state.ny.us/governor/press/year03/march4_03.htm, accessed April 15, 2003

CATEGORY: Paving Applications
CLASS: Concrete

DESCRIPTION: In this reprint of a 1991 publication, the author notes that a 1989 Connecticut study concluded that glass is not suitable for placement in portland cement concrete pavement or structures in Connecticut DOT facilities. The conclusion is mainly based on the study reported by the American Society of Testing and Materials of a 1974 study done by Johnston which indicated that glass is highly susceptible to alkali-aggregate reaction. Also, the elongated particles typical of glass cullet also present a problem with the workability of the concrete mix.

Caltrans, the state of California department of transportation, also prohibits the use of glass as an aggregate substitute in portland cement concrete, cement treated base, lean concrete base and cement treated permeable base, due to the likelihood of alkali-silica reactions.

At one point, the author says that the use of glass in portland cement concrete pavement or structures is not suitable due to alkali-silica reactions, an another point he only recommends against using glass in portland cement concrete, unless the potential problems are addressed through laboratory and field evaluations.

CONTACT: Unknown

REFERENCE: Use of Waste Materials in Highway Construction, Imtiaz Ahmed, Noyes Data Corporation, 1993, pp 52, 85, 92

CATEGORY: Paving Applications
CLASS: Concrete

DESCRIPTION: In a 1993 report of the Federal Highway Administration, US Department of Transportation, the use of glass in portland cement concrete pavement is said to be unacceptable, because "... of poor bonding (adhesion), adverse chemical reaction, and reduction in concrete strength", and references a 1991 study by Ahmed Imtiaz, Use of Waste Materials in Highway Construction, FHWA/IN/JHRP-91/3, May 1991, pages 45-55.

However, the report goes on to say that zirconsilicate glass and glass fibers or foamed glass may be capable of being beneficially used in portland cement concrete.

CONTACT: Unknown

REFERENCE: A Study of the use of Recycled Paving Material. Report to Congress. June 1993, Federal Highway Administration, US Department of Transportation, FHWA-RD-93-147, EPA/600/R-93/095, 34 pages; Appendix 1. Engineering and Environmental Aspects of Recycled Materials for Highway Construction. Final Report, US EPA and US DOT, FHWA-RD-93-088, June 1993, 212 pages

CATEGORY: Paving Applications

CLASS: Concrete

DESCRIPTION: As part of the University of Wisconsin research project on the use of glass cullet as an aggregate in concrete, the effect of the glass on the expansion of the concrete due to the alkali-silica reaction was studied. The research looked at 30 different mixes, replacing the aggregate with up to 90% glass, replacing the cement with up to 35% Class F coal ash, and using a low alkali (0.67%) cement. Compressive strengths and expansion were measured at 7, 28, 90, 180 days and after 1 year. It was found that the use of glass as aggregate generally caused a large decrease in concrete strength, and the decrease was relatively independent on the percentage of aggregate replacement with glass. Glass particle size and shape, however, did have an influence on strength, with smaller particles resulting in greater strength, and some mixes had greater strength than normal concrete after one year of curing. Expansion from the alkali-silica reaction was also large, but could be controlled by using Class F coal fly ash. It was concluded that the use of glass as aggregate in concrete was potentially feasible for lower- strength concrete applications such as pavement, parking lots, and garage slabs. It was recommended that further studies be done on long-term characteristics, including compressive strength, expansion, freeze-thaw durability, surface appearance, etc.

CONTACT: Steve Cramer, Professor of Civil & Environmental Engineering, University of Wisconsin, Room 2266, 1415 Johnson Drive, Madison, WI 53706, (608)262-7711

REFERENCE: Grant Proposals to the UW Solid Waste Research Council, 1991 & 1992; "Expansion of Glass Containing Concrete and an Introduction to the Alkali- Silica Reaction", Dipal Vimawala, an independent study report submitted in partial fulfillment of the requirements of the Master of Science, Department of Civil & Environmental Engineering, 1992, 65 pages (draft); personal memo dated September 23, 1994

CATEGORY: Paving Applications

CLASS: Concrete

DESCRIPTION: A private firm in California makes a product called Syndecrete, a lightweight concrete into which they will add various materials depending on the desire of the end user. For example, a cassette manufacturer may want cassettes used in a way that they would show up in the surface. The firm has used glass cullet as one of the additional materials. The concrete is used in non-load bearing situations, such as floors, countertops and swimming pool decks. They have used large pieces of both tempered glass and bottle glass and have applications that are 10 years old. They have not of normal concrete.

CONTACT: Syndesis, 2908 Colorado Avenue, Santa Monica, CA 90404-3616, (310)829-9932

REFERENCE: "Secondary Resources", The Construction Specifier, March 1994, page 60 and telephone conversation with firm on October 4, 1994 and company literature, received October 7, 1994

Also see CATEGORY: Concrete Applications

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: The State of California Department of Transportation has approved the use of glass cullet in road base and sub base applications.

CONTACT: Unknown

REFERENCE: Resource Recycling, September 1991, page 14, and "Market Status Report. Glass", California Integrated Waste Management Board, July 23, 1992, page 29

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: The State of New York Department of Transportation has written specifications and engineering guidelines for the beneficial use of recycled glass in paving materials. In asphalt, the present use is confined to base and binder levels to avoid the stripping problem that occurs if the glass is used in top or surface layers.

CONTACT: Garrett Dolan, (716)325-1944

REFERENCE: "Regional Highlights. Glass Hits the Streets of Central New York", in The Market, October 1991, a newsletter of the New York State Office of Recycling Market Development

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: The Lieutenant Governor of Pennsylvania announced that the State had an agreement with highway construction trade associations to use 100,000 tons of glass cullet in road construction in 1992, both in asphalt, but with more focus on other uses. The Pennsylvania Department of Transportation has issued specifications for the use of glass aggregate in asphalt and other uses. The Pennsylvania Department of Environmental Resources has also been supportive of this use of glass and did not foresee environmental problems.

CONTACT: Meredith Hill, Office of Air and Waste Management, PA Department of Environmental Resources, (717)772-2724

REFERENCE: PenCycle BBS, March 19, 1992

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: Miami County, Ohio will be using recycling glass as aggregate for the construction of a new transfer station.

CONTACT: Ted York, Miami County Solid Waste Coordinator

REFERENCE: BioCycle, November 1992, page 82

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: In this reprint of a 1991 publication, the author concludes that glass is suitable for use as either an unbound aggregate base layer if it meets gradation standards or as fill material for embankments, if crushed to the appropriate size, and these uses are recommended for the Indiana Department of Transportation.

CONTACT: Imtiaz Ahmed, Purdue University, West Lafayette, Indiana

REFERENCE: Use of Waste Materials in Highway Construction, Imtiaz Ahmed, Noyes Data Corporation, 1993, pp 52-55, 85, 92

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: The American Society for Testing and Materials has established a committee to evaluate the use of recycled material, including glass cullet, for highway construction.

CONTACT: American Society for Testing and Material, Philadelphia, PA

REFERENCE: Resource Recycling, January 1994, page 20

CATEGORY: Paving Applications
CLASS: General

DESCRIPTION: Sun Valley, Idaho and Western Mobile (Boulder, CO) are using crushed wine bottles as a substitute for sand on park trails, and in Denver, the local government and Coors are using cullet for a variety of construction uses, including drainage ditch liners and in the pavement itself.

CONTACT: Unknown

REFERENCE: "Southwestern Recyclers Learn the Latest at Annual Conference", Recycling Times, c. November 1995, pages 10, 12

CATEGORY: Paving Applications
CLASS: Paving Bricks

DESCRIPTION: A pilot plant is being established by Elizabeth City Glass to produce fused-glass products, including pavers, sandblasting abrasives, floor and wall tiles, concrete aggregate, drainage pipe, and filter media.

CONTACT: Shawn Lemmond, Elizabeth City Glass, North Carolina

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Paving Applications
CLASS: Paving Bricks

DESCRIPTION: At the Northwest Flower and Garden Show in Seattle, recycled glass pavers were used in the walkways.

CONTACT: King County Commission for Marketing Recyclable Materials

REFERENCE: Resource Recycling, March 1994, page 52

CATEGORY: Paving Applications
CLASS: Paving Bricks

DESCRIPTION: The Clean Washington Center worked with a private firm (Hot Stuff Glass) to test produce glass paving bricks and evaluate their ability to meet standards for paving bricks. The bricks were 4" by 8" (the normal for paving bricks, and of thicknesses of either 1" or 1.5"). They were designed to be used as highlights or details in areas that use clay paving bricks.

The bricks were made by crushing the glass, screen out contaminates, melting the glass, pouring the molten glass into molds, pressing the molds in some case and not pressing them in others, and then cooling the molded glass at a controlled rate (for about 7 hours) to control stress within the glass.

The bricks were tested against 4 ASTM standards: coefficient of friction, bond strength, breaking strength, and abrasive hardness. The bricks passed all standards.

An estimate was made of the capital and operating costs for a small facility to produce paver bricks from cullet. Capital costs for a facility to produce 150 pavers a day would be about \$180,000 and employ 2 people, having annual operating and debt costs of \$150,000 a year. Breakeven would price the pavers at \$5 each.

In early 1995, the Clean Washington Center was involved in several efforts to make the production of glass pavers more feasible, including: (1) a project to test breakaway molds that fit commercially available modular frames that could be used by small-scale manufacturers, (2) negotiation of a contract to develop color modification strategies, and (3) negotiation of a contract to develop information on collecting and processing recyclable container glass for use in glass art.

CONTACT: Bob Kirby, CWC, (206)389-2442 or(206)443-7746, email kirbgood@aol.com

REFERENCE: "Technology Brief. Glass Pavers", 2 pages, 1993 and Pavers from Recycled Glass. A Model for Small-Scale Pressed Glass Manufacturing, 1993, 23 pages, both from Clean Washington Center, Department of Trade & Economic Development, 999 3rd Avenue, Suite 1060, Seattle, WA 98104; personal correspondence with Bob Kirby, March 6, 1995

CATEGORY: Paving Applications
CLASS: Paving Bricks

DESCRIPTION: In Idaho, a grant was received by the Southern Idaho Regional Solid Waste District to pursue the manufacture of landscaping paving bricks from cullet. However, the District staff has run into problems with the equipment that they have been trying for grinding the glass, and so they have not been able to proceed to the manufacturing process yet.

CONTACT: Carrie Stauffer, Southern Idaho Regional Solid Waste District, PO Box 10124, Ketchum, ID 83340, (208)726-6861

REFERENCE: Telephone conversation with Carrie Stauffer, May 10, 1996

---CATEGORY: Paving Applications
CLASS: Paving Bricks

DESCRIPTION: Amazing Recycled Products Inc. of Denver, CO is making interlocking decorative pavers from 100% post-consumer glass, usable for both indoor and outdoor applications.

CONTACT: Amazing Recycled Products Inc, Denver, CO

REFERENCE: Recycling Times, September 1, 1997, page 11

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: A project is under development to use recycled glass for road construction at the landfill.

CONTACT: Ron Olson, Superintendent, Garbage Utility, 2301 8th Avenue N, Fargo, ND 58102

REFERENCE: Robert Tubbs, Waste Education and Recycling, 1200 Missouri Avenue, Bismarck, ND 58502-5520, winter 1992-93

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: A state-funded road construction project in Sacramento, California used uncleaned cullet in a test paving project.

CONTACT: Unknown

REFERENCE: Resource Recycling, December 1992, pages 92-93

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: In a recent demonstration project in Abilene, TX, an entire year's supply of the city's recovered glass (229 tons) was used in a nearby highway project. The glass represented only 10% of a 500-foot section of road, according to Rebecca Davio, recycling coordinator for the Texas Department of Transportation.

CONTACT: City of Abilene or Rebecca Davio, Texas DOT

REFERENCE: Waste Age, August 1997, page 51

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: A 1995 report of the South Carolina Recycling Market Development Advisory Council says that the SC Department of Transportation will be using recovered glass as an aggregate in a 1996 roadway project.

CONTACT: South Carolina DOT

REFERENCE: Resource Recycling, April 1996, page 11

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: Ocean City, Maryland is processing glass bottles to make cullet to be used in road construction and paving projects.

CONTACT: Richard Malone, Town of Ocean City, MD Department of Public Works, (410)524-7715

REFERENCE: Resource Recycling, April 1995, page 120; personal communication from Andela Tool & Machine, August 1995

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: The Town of Ocean City, Maryland, has purchased a glass crushing system to crush the glass bottles collected for recycling and will be using the crushed glass as aggregate by the municipality in their road construction projects.

CONTACT: Town of Ocean City, Maryland or Keith Lauver, Recycling Systems USA, (610)543-0860

REFERENCE: Waste Equipment News, November 1995, Section A, page 16

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: The Western Minnesota Department of Transportation is experimenting with the use of recycled materials -- including glass -- in highway construction. In a 1994 update, two projects for the use of recyclable glass are briefly listed: (1) a project with Sibley County in which 10% crushed glass is used with aggregate to construct a base course, and (2) a project with an asphalt contractor to use up to 5% crushed glass in asphalt.

CONTACT: Roger Olson, MN DOT, Materials and Research Laboratory, 1400 Gervais Avenue, Maplewood, MN 55109, (612)779-5517

REFERENCE: The Use of Tires and Glass in Highway Construction, DPRA Environmental Consulting and Waste Alternatives Consulting, 1994, pages 2-3

CATEGORY: Paving Applications
CLASS: Road Construction

DESCRIPTION: The Western Research Institute assessed the environmental and engineering aspects of using recycled material in highway construction, including glass, looking at 5 potential applications:

1. Aggregate in asphalt paving
2. Aggregate in unbound base courses
3. Mixing with embankment soils
4. Glass beads in line striping
5. Pipe bedding and filter materials in pavement edge drains

They also concluded that the use of glass in portland cement concrete was not feasible because of poor bonding, adverse chemical reaction and reduction in concrete strength, citing a May 1991 article by Ahmed Imtiaz through the FHWA (report number FHWA/IN/JHRP-91/3).

For the use of glass in asphalt, the report that the use of glass is feasible to a maximum of 15%, with a recommendation that it be used in the wearing course only on low-speed and low volume pavements, or in the base course in other situations.

The use of glass in embankments and fills is described as the preferred method of using glass in highway projects.

As a drain material used in french drains, the only limitation listed was to use a geotextile to act as a filter to prevent clogging of the drain, similar to the need to its use with other aggregates.

CONTACT: Western Research Institute, Laramie, WY 82071

REFERENCE: Engineering and Environmental Aspects of Recycled Materials for Highway Construction, Western Research Institute, Laramie, WY, July 1993, pages 106-112 and 197-198

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Abilene, Texas has been using pulverized glass as road base. It also has used this glass for golf course sand traps, sand filter and pipe bedding applications.

CONTACT: The City of Abilene, Texas

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

-----CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Aloha Glass Recycling of Maui, Hawaii, put over 1,500 tons of processed glass into the paving market so far in 2002.

CONTACT: Tom Reed, Aloha Glass Recycling, Maui, Hawaii

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The state Department of Environmental Services is working with a road building company to incorporate the use of glass cullet in road building programs.

CONTACT: New Hampshire Department of Environmental Services

REFERENCE: "Concord, New Hampshire. Recycled Glass to be Used in Road Base Aggregates", BioCycle, September 2002, page 22

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The Wisconsin Department of Transportation is testing the use of 10% cullet in the aggregate of the roadbase of the reconstruction of Highways 12-18 between Madison and Cambridge. The project will use about 250 tons of green glass. The project is a demonstration project supported by the Wisconsin Recycling Market Development Board.

CONTACT: Elizabeth Olenbush, Wisconsin Recycling Market Development Board, olenbush@worldnet.att.net, (516)472-9784

REFERENCE: same as above, summer 1998

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: In Minnesota, both the state and several counties have used glass cullet as a roadbed aggregate. The work started in 1991, when Sibley County and the MN DOT tested a blend of recycled glass with aggregated. Currently, projects are underway as follows:

- Cass and 5 other counties are working on a joint project to test a variety of uses of glass as an aggregate in north central Minnesota, including a discussion of a regional glass processing facility.
- Ramsey County in the Twin Cities metropolitan area successfully used crushed, screened glass in a 1997 project to reconstruct Larpenteur Avenue, using 10% cullet in aggregate base and a 5% cullet with recycled concrete and bituminous. The second mixture was found to be easier for the contractor to use. In 1998, a test will be done on Larpenteur for 100% cullet in the first 3 inch layer of the two foot thick subgrade correction.
- Hennepin County, also in the Twin Cities Metro Area, tested the use of crushed glass in road based aggregate along County Road 47. The glass improved permeability, strength and performance in freezing and thawing conditions. They have also tested glass in the asphalt on the same road; this worked so well that they used crushed glass in the base and binder courses of the parking lot and driveway at the Public Works Center.
- Houston County mixes glass with gravel to produce a Class 5 aggregate.
- Lake of the Woods County is also mixing glass with aggregate and finds that the result is superior to aggregate alone.
- Otter Tail County is testing a mix of container glass, window glass and Pyrex to form a Class 5 aggregate, which it will test in the summer of 1998.

CONTACT: Deborah Carter McCoy, Minnesota Office of Environmental Assistance, (612)215-0287 or Dan Krivit, consultant, (612)489-4990

REFERENCE: "Recycled Glass Finds New Purpose in Road Construction", Deborah Carter McCoy and Dan Krivit, and "Counties Recycle Mixed Glass in Local Projects", The Resource, Minnesota Office of Environmental Assistance, pp 8, 16, Spring 1998

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: In 1996, glass cullet was used as road bed aggregate in the reconstruction of a 4,000 foot long section of street in Devine, Texas. More than 435 tons of glass were used in the project, in accordance with the Texas DOT standards of no more than 20% glass by weight in the base material.

CONTACT: Unknown

REFERENCE: World Wastes, February 1997, pages 9-10; Resource Recycling, May 1997, page 76

--- CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: In January 1997, The City of Oberlin, Ohio laid down a mixture of 30% crushed cullet and 70% limestone as a sub-base for a road construction project, over which asphalt was applied. A total of 125 tons of glass were used in the project.

CONTACT: City of Oberlin, Ohio recycling coordinator

REFERENCE: "Oberlin, Ohio. Utilizing Cullet for Road Base", BioCycle, February 1997, page 25, "City Uses Mixed Glass Cullet in Roadbeds", Recycling Today, February 1997, page 22 and Letter to the Editor, MSW Management, January/February 1997

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The Town of Dryden, Ontario uses cullet as base aggregate in road construction, mixed at 10% or less with pit run gravel.

In addition, the town uses cullet for drainage aggregate in trench drains and in French drains in parkland and residential subdivision work. The Town has also provided cullet to the private sector for use over weeping tile in new house construction.

The town is also negotiating with the province to use cullet as a drainage aggregate in septic filed construction.

CONTACT: M. Fisher, Town of Dryden, 30 Van Horne Avenue, Dryden, ON P8N 2A7, (807)223-2367

REFERENCE: Personal letter from M. Fisher, May 13, 1996

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Warner, New Hampshire, with 2,000 people, collects about 50 tons of cullet a year, which is used as roadbed aggregate and other road construction uses.

CONTACT: Dan Lavoie, Town of Warner, (603)456-3303

REFERENCE: Telephone conversation with Dan Lavoie, May 10, 1996

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The Oneida/Herkimer County, NY MRF processes about 5 tons of cullet a day for use as road bed material and landfill cover.

CONTACT: Steve DeVan, Oneida/Herkimer County MRF, (315)733-1224

REFERENCE: Personal communication from Andela Tool & Machine Co, August 1995

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The use of glass as subbase for road shoulders is under study in Minnesota as a method to improve drainage of water from underneath the roads. Current gravel apparently contains too

much fine material, which becomes compacted and reduces drainage. A suitable construction site is being sought for test use in 1995. Hennepin County is the lead agency.

CONTACT: Minnesota Recycling Market Development Program, (612)296-3417

REFERENCE: Personal telephone conversation with staff of the Minnesota Recycling Market Development Program, April 28, 1995

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Portage County, Wisconsin received a state grant to produce roadbase material from 10% waste glass and 90% gravel and to test this material against the specifications of the Wisconsin Department of Transportation, using 11 AASHTO tests. One of the goals of this project is to increase the amount of P200 material in the roadbase; some of the current gravel falls short of state standards.

In the analysis of the potential to use glass for roadbed aggregate, it was calculated that the County Highway Department could use more aggregate than what was available from local recycling programs. At first, the project looked at using the glass without any processing at the MRF, taking the glass straight to the gravel pit for processing with gravel processing equipment. There were no major problems encountered in the processing. There was, however, a problem in measuring the gradation of the glass --it was first washed, and then dried before the analysis was done, and in the drying process, the glass would melt, skewing the results, resulting in a failure to meet the <P200 requirements. It was concluded that the glass should instead go through a glass crusher to produce the gradation needed. In the test application, 5,000 tons of gravel were used on a 2 mile stretch of road, 3" deep and 28' wide. The glass compacted well, providing greater compaction than gravel, and resulted in less raveling of the road. Glass is especially beneficial for roadbed construction where there is poor quality gravel.

Because gravel is inexpensive in Portage County (\$1-4) a ton, and the use of glass in the roadbed did not save any processing costs at the Material Recycling Facility, the economics of this project did not benefit the county.

CONTACT: Stefan Fabian, Landfill Manager, Portage County Solid Waste Department, 817 Whiting Avenue, Stevens Point, WI 54481, (715)592-4663

REFERENCE: February 1, 1993 grant application of Portage County to Wisconsin DNR and May 17, 1993 DNR fact sheet, presentation at the AROW recycling conference, March 7, 1995

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Palm Beach County, FL is using mixed color cullet from its MRF as aggregate for roadbeds at its landfill.

CONTACT: Scott Riemer, The Solid Waste Authority of Palm Beach County, FL, (407)471-2700

REFERENCE: Personal telephone conversation, February 13, 1995

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: In England, the glass trade association has looked at a variety of potential uses for glass cullet, including roadbed aggregate. They believe that this use could consume substantial quantities of cullet, but that there would be the problem of size grading.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256- 258

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Orange County, NY used 70 pounds of crushed glass per square yard mixed in with reclaimed roadbed aggregate, using 600 tons of glass in a 6,000 foot long road project. The road was then finished with asphalt.

CONTACT: Joseph Provost, Orange County, NY Commissioner of Public Works, or Mike Haggerty, Reclamation Inc, Kingston, NY

REFERENCE: "Waste Glass Serves as Road Aggregate", Public Works, May 1994, pp 52-53, 94-95

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Pierce County, Wisconsin is using scrap glass as aggregate for roadbeds.

CONTACT: Troy Gansluckner, Solid Waste Administrator, Pierce County Courthouse, PO Box 118, Ellsworth, WI 54011, (715)273-3092

REFERENCE: Resource Recycling, January 1994, page 55

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The City of Regina, Saskatchewan has been using crushed glass as 10% of its road sub-base and road asphalt.

CONTACT: Unknown

REFERENCE: Resource Recycling, July 1993, page 68

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The New Hampshire Governor's Recycling Program has completed a study of crushed glass and ceramic containers for use as Processed Glass Aggregate (PGA) as roadbase material in conjunction with the New Hampshire Department of Transportation (NH DOT). The project proved successful and the NH DOT has written specifications for its use (contact is Fred Prior at (603)271-1653) and the NH Resource Recovery Association has received a grant to promote its use.

CONTACT: Elizabeth Bedard, Governor's Recycling Program, Office of State Planning, 2 1/2 Beacon Street, Concord, NH 03301, (603)271-1098

REFERENCE: Personal Correspondence with Elizabeth Bedard, April 9, 1993

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: The New London, NH road agent has built a glass crusher for \$2,000 and uses the cullet as a gravel supplement in road bed construction, with the best compaction from a 50/50 mixture of gravel and cullet under a two inch layer of asphalt.

CONTACT: Unknown

REFERENCE: Resource Recycling's Bottle/Can Recycling Update, February 1993, page 7

CATEGORY: Paving Applications
CLASS: Roadbed Aggregate

DESCRIPTION: Glass cullet is mixed with rock to make a (MN class 5) roadbed aggregate. This has been approved by the Minnesota DOT and Minnesota Pollution Control Agency, and is being used in Pennington County, MN.

CONTACT: Unknown

REFERENCE: The Minnesota Project, July 1992

CATEGORY: Remelt Applications
CLASS: Art Glass

DESCRIPTION: Aurora Glass Foundry of Eugene, Oregon produces a variety of architectural and decorative glassware, using 100% recycled glass. It is part of Saint Vincent de Paul's recycling program.

CONTACT: Aurora Glass, (888) 291-9311

REFERENCE: Internet web pages, <http://www.auroraglass.org/>,
<http://www.svdplanecounty.org/mainsite/recycling/aurora.html>, accessed July 1, 2003

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CATEGORY: Remelt Applications
CLASS: Art Glass

DESCRIPTION: Amazing Recycled Products makes a variety of recycled glass paperweights, wind chimes, award plaques, gift boxes and other art glass objects.

CONTACT: <http://www.amazingrecycled.com/>, accessed March 18, 2003

REFERENCE: Internet web page, <http://www.amazingrecycled.com/>

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CATEGORY: Remelt Applications
CLASS: Art Glass

DESCRIPTION: Bedrock Industries of Seattle, Washington primarily makes glass tiles, but on Valentine's Day each year, the firm throws handmade hearts made from 100% recycled glass into Puget Sound (perhaps like in "Harold and Maude"?). The firm recycles about 200,000 pounds of glass a year.

CONTACT: Maria Ruano, Bedrock Industries, Seattle, WA

REFERENCE: "Seattle, Washington. Valentine's Day on Puget Sound Features Recycled Glass Hearts", [BioCycle](#), February 2003, page 16

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---CATEGORY: Remelt Applications
CLASS: Art Glass

DESCRIPTION: At Tulane University there is a very active glassblowing department, which uses all of the university's sorted clear and green glass as well as glass from local bars to make art.

CONTACT: Emery Myers, Recycling Coordinator, Tulane University, hmyers@mailhost.tcs.tulane.edu

REFERENCE: Email message, October 22, 1998

---CATEGORY: Remelt Applications

CLASS: Art Glass

DESCRIPTION: Art glass is being made from clear glass bottles. In an undated brochure, they say they are using 40 tons of scrap cullet a month. There may be the potential to use colored glass bottles and jars to make colored windows or stained glass.

CONTACT: Lani McGregor, Bullseye Glass Co., 3722 SE 21st Avenue, Portland, OR 97202, phone (503)232-8887

REFERENCE: Association of Oregon Recyclers, 1/23/1993; Bullseye Glass Co., 4/20/1993

CATEGORY: Remelt Applications

CLASS: Art Glass

DESCRIPTION: An art glass manufacturer has received a grant from the State of Wisconsin for the manufacture of various types of glass-related products from glass cullet, including stained glass, blown glass, pressed glassware, glazed terrazzo tile, and jewels and beads. They found that the melting process worked very well; in melting glass daily for a year, they had no significant problems. They also had good results in both making blown glass and glass tiles. For the blown glass, the process was somewhat more difficult than with virgin glass (for example, the working time was shorter), but having a glass blower who had a lot of expertise helped to overcome the problems. The glass tiles were actually better than ceramic tiles, being impervious to moisture and having better strength. On the other hand, the company did not have good results for making sheets of glass -- the results were too unpredictable and the coefficients of expansion were unequal, making it impossible for artists to use in jewelry, dishes, etc. The company has both decided to use glass cullet further and is working with university faculty on ways to overcome the problems with the glass sheets.

CONTACT: Ray Selk, Chicago Art Glass and Jewels, Inc., 937 Pilgrim Road, Plymouth, WI 53073, (920)892-2744

REFERENCE: Grant application from Chicago Art Glass to the Wisconsin Department of Natural Resources; final report to DNR, December 1992; two March, 1993 grant applications to the University of Wisconsin Solid Waste Research Council; and "Creating Local Jobs from Environmental Protection. Focus on Recycling and Small Business", March 1992, T. Paul Robbins, et. al, (city, organization unknown; received from Erv Sandlin, Texas Water Commission)

CATEGORY: Remelt Applications

CLASS: Art Glass

DESCRIPTION: The Clean Washington Center is negotiating a contract with a glass art technical expert to develop information on collecting and processing recyclable container glass for art glass.

CONTACT: Bob Kirby, CWC, (206)443-7746, email kirbgood@aol.com

REFERENCE: Personal correspondence with Bob Kirby, March 6, 1995

CATEGORY: Miscellaneous
CLASS: Abrasive

DESCRIPTION: CWC and TriVistro Corporation have been studying the use of glass as an abrasive. While sand has long been used as an abrasive, the health problems related to silicosis from sand have led to searches for other materials. Glass, as an amorphous form of silica, does not present the silicosis problems that sand does.

Many other materials -- ranging from walnut shells to steel shot -- are used as abrasives. The niche for glass seems to be in the low-end blasting abrasives, with competing abrasives selling for \$80 to \$120 a ton.

CWC sponsored research on the use of both container glass and plate glass as abrasives, sponsoring both performance testing and testing of equipment to produce the abrasive.

In the performance testing, it was found that glass is similar in many respects to silica sand. Container glass was somewhat better than plate glass in breakdown rate and cleaning rate. Surprisingly, the glass also imparted to steel surfaces a characteristic to not "rust back" as quickly as some other abrasives.

TriVistro and CWC have spent several years working on the production side of making glass abrasive. Quality control was an especially significant issue, along with testing to prove that it meet industry specifications. After extensive tests, it has been certified by the California Air Resources Board for meeting dust standards, as have competing products from other cullet recyclers.

Another hurdle to overcome is the handling of the residue from the use of glass as an abrasive. For other abrasives, the residue can often be used by cement kilns. But due to the alkali nature of glass, cement kilns do not want the glass abrasive residues, and the cost of alternative disposal is a barrier to some uses of glass abrasive. Additional work is being done to develop end uses for the residues.

CONTACT: Bob Kirby, CWC, (206)443-7746, or web page <http://www.cwc.org>

REFERENCE: "Abrasive Markets - A New Opportunity for Recovered Glass", Bob Kirby, Resource Recycling, September 1998, pages 36-41

--CATEGORY: Miscellaneous
CLASS: Abrasive

DESCRIPTION: AMV, LLC of La Crosse, WI has received funding from the Wisconsin Recycling Market Development Board to produce an foamed glass abrasive made of recycled glass for use in the stone washing industry, such as for washing denim jeans. Currently, the stone washing industry uses an estimated 53,000 tons of pumice annually, with material largely imported from Ecuador and Turkey. The glass recycling process is initially expected to consume about 40 tons of mixed color glass a month, increasing thereafter. The pilot project is expected to take four months, at which point the firm will be able to determine if the product can be commercialized.

In addition to the stone washing product, the firm is expecting to research other uses for foamed glass products for finishing, coatings removal and surface preparation and personal hygiene.

CONTACT: AMV, LLC, La Crosse, WI

REFERENCE: Recycling Technology Assistance Proposal of AMV, LLC, presented to Wisconsin Recycling Market Development Board, June 12, 1998; "Alternative Uses for Cullet Found", Glass Industry, August 1998, page 7

---CATEGORY: Miscellaneous
CLASS: Abrasive

DESCRIPTION: Dunkirk International Glass and Ceramics of Dunkirk, NY is developing a system to recycle television glass (tubes and tube glass) to produce an abrasive.

CONTACT: Dunkirk International Glass and Ceramics, Dunkirk, NY

REFERENCE: Resource Recycling, July 1994, page 73

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CATEGORY: Miscellaneous
CLASS: Abrasive

DESCRIPTION: Universal Ground Glass makes abrasives and other products from glass cullet, principally pre-consumer plate glass.

CONTACT: Universal Ground Cullet, Inc., 5181 West 161st Street, Cleveland, OH 44142, (216)267-8057, fax (216)267-8063

REFERENCE: 1996 Glass Industry Directory Issue, Volume 77, Number 3, page 107; Internet message from George Peters, Ohio Division of Recycling and Litter Prevention, January 16, 1996

CATEGORY: Miscellaneous
CLASS: Agricultural Fertilizer

DESCRIPTION: An art glass manufacturer received a grant from the State of Wisconsin on the manufacture of various types of products from glass cullet, including an agricultural fertilizer. However, the final report contained no information on this potential use.

CONTACT: Ray Selk, Chicago Art Glass and Jewels, Inc., 937 Pilgrim Road, Plymouth, WI 53073, (920)892-2744

REFERENCE: Grant application and final report (1992) from Chicago Art Glass and Jewels, Inc. to the Wisconsin Department of Natural Resources.

CATEGORY: Miscellaneous
CLASS: Beach Sand

DESCRIPTION: The New Zealand community of Lake Hood has built a beach from finely-ground glass bottles

CONTACT: the city of Lake Hood, New Zealand

REFERENCE: Resource Recycling, January 2003, page 35

CATEGORY: Miscellaneous
CLASS: Beach Sand

DESCRIPTION: An American chemist -- Dr. Dan Dalagar -- is reported to have received approval to 'rebuild' the California coasts being eroded by the Pacific Ocean by 'breaking bottles down into fine particles', according to an article in the Reflections section of Glass magazine (England), which goes on to say "Just think of the potential - an industry making sand from glass from sand!"

CONTACT: Unknown

REFERENCE: Glass, August 1993, page 289; original information from the British Glass Review

CATEGORY: Miscellaneous
CLASS: Ceramic Glazes

DESCRIPTION: Tests are being done to develop ceramic glazes out of glass, especially light green bottle glass, plate glass, and possibly boro-silicate glass from lamps. The goal is to finish with the laboratory tests by February, 2000, and then put together a prototype manufacturing facility to test market the products.

CONTACT: John Clifford, Banks, OR, email jclifford@bigplanet.com

REFERENCE: email message from John Clifford, January 26, 2000

CATEGORY: Miscellaneous
CLASS: Designer Clothes

DESCRIPTION: Nancy Judd, executive director of the New Mexico Recycling Coalition, organizes fashion shows where the dresses are made of recycled material. In a dress sponsored by the Glass Packaging Institute of Alexandria, VA, the dress had about 12,000 pieces of crushed clear cullet from an Albuquerque sorting plant individually glued onto the dress.

CONTACT: Nancy Judd, New Mexico Recycling Coalition, Santa Fe, NM

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous
CLASS: Filler for Plastics

DESCRIPTION: Crushed glass is being tested as a plastics filler for injection molding. Approximately 7-8% glass appears to work as a filler. The crushed glass is produced by a machine developed by Bosh-Silica of Idaho.

CONTACT: Bob Copeland, Bosh-Silica, 679 N. Five Mile, Boise, Idaho 83713, (208)376-0945

REFERENCE: Telephone conversation with Bob Copeland, January 30, 1998

CATEGORY: Miscellaneous
CLASS: Filters (General)

DESCRIPTION: The Maryland Port Administration plans to use 50,000 tons of scrap glass ground to 1/2" minus in size as a filtering medium in the dewatering of slurry dredged from the Chesapeake Bay by the US Army Corps of Engineers.

CONTACT: The Maryland Port Administration, Baltimore, web page <http://www.mpa.state.md.us/>

REFERENCE: "Glass", Resource Recycling, March 2003, page 41

---CATEGORY: Miscellaneous

CLASS: Filters (General)

DESCRIPTION: Abilene, Texas has been using pulverized glass sand filters, for road base, in golf course sand traps and pipe bedding applications.

CONTACT: The City of Abilene, Texas

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

---CATEGORY: Miscellaneous

CLASS: Filters (General)

DESCRIPTION: A pilot plant is being established by Elizabeth City Glass to produce fused-glass products, including filter media, sandblasting abrasives, pavers, floor and wall tiles, and concrete aggregate.

CONTACT: Shawn Lemmond, Elizabeth City Glass, North Carolina

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous

CLASS: Filters (General)

DESCRIPTION: A private consultant in New York state is researching the use of glass cullet as a water/wastewater filtering media, as a method to produce a value-added product that offers advantages over other alternative materials. He is researching this approach with funding from the state of New York.

CONTACT: Tom Higgins, PO Box 407, Penfield, NY 14526, telephone (716)377-5484

REFERENCE: Telephone conversation with Tom Higgins, April 17, 1996

CATEGORY: Miscellaneous

CLASS: Flat Glass

DESCRIPTION: In Iowa, Guardian Industries Corporation is building a manufacturing plant in DeWitt to produce 700 tpd of windows, mirrors, and door glass. The facility will use 20-30% cullet, including, possibly, cullet from curbside programs.

In Corsicana, Texas, Guardian Industries uses 2,000 tons of clear and light green container glass [per year] to manufacture plate glass, buying from Allwaste, individual brokers, and some communities.

CONTACT: Gary Ferguson, Purchasing Agent, Guardian Industries, 3801 Hwy 287S, Corsicana, TX 75110, (903)872-4871

REFERENCE: "Iowa Recycling Markets See Growth", Chaz Miller, Recycling Times, October 31, 1995; email message from Oscar Carrillo, Texas Natural Resource Conservation Commission, March 1, 1996

CATEGORY: Miscellaneous

CLASS: Floor Grit

DESCRIPTION: The Clean Washington Center is testing the use of cullet as a grit for industrial flooring, and it has worked well with resin binders, such as wheelchair ramps, coefficient of friction floors, etc.

CONTACT: Bob Kirby, CWC, (206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: Personal correspondence with Bob Kirby, March 6, 1995

CATEGORY: Miscellaneous
CLASS: Flowable Fill

DESCRIPTION: A research project is being done at the University of Wisconsin-Milwaukee to test the use of mixed color glass from material recycling facilities in a flowable fill known as Controlled Low Strength material. The research for the first year will be laboratory work, and, if successful, will be expanded to a pilot field application in the second year. The slurry would consist of a large quantity (~40%) of fine (< 1/4") glass with a small amount of cement (3%) along with coal ash (~27%) and water (30%). Strengths of about 50 to 200 psi are expected. The slurry would be used as a pumpable, self-leveling backfill, such as for pavement subbase, utility trenches, foundation backfill, etc.

The test will look at a minimum of six different mixtures of varying percentages of glass. Tests would be done of the compressive strength, bleedwater, shrinkage, setting characteristics, and reactivity of the glass with the cement.

A final report is expected by the end of 1998.

CONTACT: Dr. Tarun Naik, University of Wisconsin-Milwaukee Center for By-Products Utilization, tarun@uwm.edu, Internet site <http://www.uwm.edu/Dept/CBU>

REFERENCE: April 1997 proposal on "Development of Flowable Slurry Utilizing Mixed Glass" to the University of Wisconsin Solid Waste Recovery Research Program, July 1998 email message from Dr. Tarun Naik

CATEGORY: Miscellaneous
CLASS: Gas Treatment

DESCRIPTION: Research at a landfill in Bavaria, Germany has found that using glass as an aggregate in gas extraction systems provides treatment of the gas and removal of corrosive components.

CONTACT: Bayerischer Forschungsverbund Abfallverwertung und Reststoffverwertung (BayFORREST), Munich, Germany.

REFERENCE: Internet Web Page <http://www.deponieforschung.de/seite.php?navi=4|1|projekt|F102|1|en>, accessed July 1, 2003

CATEGORY: Miscellaneous
CLASS: General

DESCRIPTION: A private firm has patented a process to recycle all types of non-hazardous glass into a variety of products, including aggregate, fiberglass, glassphalt and for the cement industry.

CONTACT: Bessa Waste Management, Guelph, Ontario

REFERENCE: Recycling Times, November 29, 1994, page 8

CATEGORY: Miscellaneous
CLASS: General

DESCRIPTION: The collector for the city of Telluride, Colorado, population 1,300, is processing mixed-color cullet from the municipal recycling program into three sizes for reuse as filtering material, sandblasting, and aquariums.

CONTACT: Burbridge Trash Service, Nucla, CO

REFERENCE: Resource Recycling, December 1994, page 42

CATEGORY: Miscellaneous
CLASS: General

DESCRIPTION: Equipment has been produced to crush glass into "sand", which the equipment manufacturer claims can then be used for a variety of purposes, including golf course maintenance, sand blasting, concrete additives, water filtration, backfill drainage and aquarium aggregate. In 1994, they announced that they were building a factory to process glass for used in fiberglass, paint and golf course maintenance. In the summer of 1994, the company won a 2 year contract to supply its GlasSand product to the Edmonton plant of Fiberglas Canada.

CONTACT: Vitreous Environmental Group, Inc., maker of the GlassBlaster, PO Box 3202, Airdrie, Alberta T4B 2B5, Canada, (403)948-7811

REFERENCE: BioCycle, December 1992, page 87; Recycling Today, September 1992, pages 30-31; literature from Vitreous Environmental Group, September 16, 1993, Resource Recycling, May 1994, page 77, Resource Recycling, September 1994, page 15

CATEGORY: Miscellaneous
CLASS: General

DESCRIPTION: Equipment has been produced to pulverize glass, which can then be used for a variety of purposes, including a neoprene product known as F.G. 5000, which is said to use 75% pulverized glass.

CONTACT: Recycling Technologies Unlimited (RTU), PO Box 262, Mohawk, NY 13407, (315)894-6889

REFERENCE: RTU literature announcing conferences titled "Profits of Pulverizing", December 28, 1992

CATEGORY: Miscellaneous
CLASS: General

DESCRIPTION: A patent has been issued for a process to make construction products using a variety of plastics as the binder, and a variety of waste materials -- including glass cullet -- as the filler.

CONTACT: Virgil Folsom, Springfield, MO

REFERENCE: US patent 5,312,858, issued May 17, 1994

CATEGORY: Miscellaneous

CLASS: General

DESCRIPTION: Hawaii Cracked Glass Products uses recycled glass and special tints to produce planters, stepping stones, landscape edgings and other decorative items, such as soap dishes and candle holders.

CONTACT: Recycling Systems Hawaii, 485 Railroad Ave., Hilo, HI 96720, (808)959-1712, (808)959-0361

REFERENCE: Resource Recycling, November 1997, page 59

CATEGORY: Miscellaneous

CLASS: Glass Beads

DESCRIPTION: Using the Thomas Register, a letter was sent to companies that produce glass beads, asking for information if the beads are made of recycled glass. The following companies have stated that their beads are made from recycled glass:

The Quackenbush Company
500 E. Main Street
Lake Zurich, IL 60047
(708)438-5090

GAMM Industries, Inc.
N85 W13780 Leon Road
Menomonee Falls, WI 53051
(414)251-5060

Potter Industries Inc.
20 Waterview Blvd
Parsippany, NJ 07054
(201)299-2900

Fairmount Abrasives
PO Box 236
Wedron, IL 60557
(815)792-8055

Northeastern Safety Products, Inc.
PO Box 444
East Rutherford, NJ 07073
(201)438-2313

One firm also said that most glass beads are made of recycled glass, since that is the cheapest way to manufacture glass beads.

CONTACT: Individual companies.

REFERENCE: Summer, 1993 survey by John Reindl, Dane County Recycling Manager, 1919 Alliant Energy Center Way, Madison, WI 53713, (608)267-8815

CATEGORY: Miscellaneous

CLASS: Glass Beads

DESCRIPTION: Canasphere (Moose Jaw, Saskatchewan) uses about 250 tons of cullet per month to produce reflective glass beads.

CONTACT: Canasphere, Moose Jaw, Saskatchewan

REFERENCE: Bottle/Can Recycling Update, June 1993, page 3

CATEGORY: Miscellaneous

CLASS: Glass Beads

DESCRIPTION: Mixed-color cullet makes a highly reflective supplement for highway paint according to research at the University of Missouri-Rolla.

CONTACT: Dennis Roedemaier, Missouri Enterprise, University of Missouri-Rolla, (314)364-8570

REFERENCE: Bottle/Can Recycling Update, July 1993, page 4

CATEGORY: Miscellaneous
CLASS: Glass Beads

DESCRIPTION: The following firms in Texas make glass beads from cullet:

Flex-O-Lite Inc.
Eldon Foster, Plant Manager
1601 19th NW
Paris, TX
(903)785-1633

Potter Industries Inc (Southwestern Division)
Gary Whyte, Plant Manager
HC-30 Box 20
Brownwood, TX 76801
(915)752-6711

OMEGA Raz-R-Tex
Robert Counts, President
PO Box 747
Panhandle, TX 79068-0747

CONTACT: Individuals from above firms

REFERENCE: Email from Oscar Carrillo, Texas Natural Resource Conservation Commission, March 1, 1996

CATEGORY: Miscellaneous
CLASS: Glass Beads

DESCRIPTION: The 1996 Glass Industry Directory lists the following companies that make glass beads:

Cataphote Inc.
PO Box 2369
Jackson, MS 39225-2369
(601)939-4612
(601)932-5339 fax

Champion Agate Co. Inc.
107 Industrial Drive
Pennsboro, WV 26415
(304)659-2861

Corning Inc.
Corning, NY 14831
(multiple plants)
(607)974-9000

Emerson & Cuming, Inc.
59 Walpole Street
Canton, Ma 02021
(617)821-4250
(617)821-0737 fax

English Glass Co.
Scudamore Road
Leicester, LE3 IUG ENGLAND
(0116) 233 1111

Epsom Glass Industries Ltd.
Longmead
Epsom, Surrey KT19 9AN ENGLAND
(01372) 740011

(0116)231 2077 fax

Flex-O-Lite, Inc.
101 S. Hanley Road
St. Louis, MO 63105
(314)862-2444
(314)889-6905 fax

Glassco, Ltda., Vidrio Cristal
PO Box 91765
Bogota COLUMBIA
247 8222

Marble King, Inc.
PO Box 195
Paden City, WV 26159
(304)337-2264
(304)337-8242 fax

Nippon Electric Glass Co., Ltd.
7-1, Seiran 2-Chome,
Otsu, Shiga Pref. 520 JAPAN
0775 (37) 1700
5462-892 NEG Telex

Pannonglas Industrial Co., Ltd.
Erzsebet kiralyne utja 112
H-1142 Budapest HUNGARY
251-2888
251-2108 fax

Potters Industries, Inc.
PO Box 840
Valley Forge, PA 19482
(Has 21 mfg/fabricating plants)
(610)651-4700
(610)408-9723

Richland Glass Co., Inc.
PO Box 249
Richland, NJ 08350
(609)691-1697
(609)691-4525 fax

Sem-Com Co., Inc.
PO Box 8428
Toledo, OH 43623
(419)537-8813
(419)537-7054

D. Swarovski & Co.
Wattens A-6112 AUSTRIA
(05224) 500-0
(05224) 52335 fax

(01372) 741297 fax

Glass Company of America
PO Box 230
Milville, NJ 08332
(609) 825-0305

Glaverbel S.A
Chee de la Hulpe 166
Brussels B-1170 BELGIUM
02/674.31.11
02/672.44.62 fax

Mo-Sci Corp.
PO Box 2
Rolla, MO 65401
(314)364-2338

Ohara, Inc.
15-30 Oyama 1-chome
Sagamiharashi, Konagawa 229 JAPAN
0427 (72) 2101
0427 (74) 2314 fax

Peltier Glass Co.
PO Box 490
Ottawa, IL 61350
(815)433-0026

Potters-Ballotini Ltd.
Pontefract Road
Barnsley, South Yorkshire S71 1HJ
ENGLAND
Barnsley (01226) 770381

Salvadori, Ets.
165, Avenue Roger Salengro
69120 Valux-en-Velin (Rhone) FRANCE
Lyon 72.37.50.14

Sovitec S.A.
Avenue du Marquis, Zoning Industriel
B-6220 Fleurus BELGIUM

Taiwan Union Glass Industrial Co. Ltd.
803 Po Ai Street
Chupei Hsinchue TAIWAN
02-7027126
02-7088678 fax

Teknik Cam Sanayii A.S.
Davutpasa Cd. Cebealibey
Sk. No. 16
Istanbul TURKEY
0-212-5760479
0-212-6123922 fax

Toshiba Glass Co. Ltd.
3583-5, Kawashiri
Yoshida-Cho Haibara-Gun
Shizuoka 421-03 JAPAN
0548-32-7654
0548-32-9602 fax

Turkiye Sise VeCam Fab. A.S.
P.K. 175
80706 Besiktas, Istanbul TURKEY
(0212)274 72 00
26 963 PCAM TR Telex

Winsted Precision Ball Co.
PO Box 679
Winsted, CT 06098-0679
(203)379-2788
(203)379-9650 fax

ZBS Glass Co.
468 22 Zelezny Brod
Prumyslova 702 CZECH REPUBLIC
42-428-76611
42-428-766501

Although the company listings do not say whether the beads are made from cullet, as noted in an earlier reference, cullet is the most common raw material for glass bead manufacturers.

CONTACT: Individual companies

REFERENCE: 1996 Glass Industry Directory Issue, Volume 77, Number 3

Also see: CATEGORY: Miscellaneous, CLASS: Reflective Beads

CATEGORY: Miscellaneous
CLASS: Glass Foam

DESCRIPTION: A European firm, Hasopor, produces a foam glass from a variety of recycled glass materials. The foam glass can be used as a low weight fill for a variety of construction projects, including road fill. In a project in Norway, it is being used as a fill material over a tunnel along one of their major roadways, E6. The business plan of the firm is to provide 500,000 cubic meters of material to the European market by 2005.

CONTACT: Hasopor AG, Grossenhain, Germany and Miljøtek Hasopor AS, Meraker, Norway, Hasopor Web page, http://www.hasopor.com/hasopor_intro/intro/english.html

REFERENCE: Article in Adresseavisen, June 18, 2002, accessed on the Internet at <http://www.adresseavisen.no/nyheter/okonomi/article.jhtml?articleID=347388>, Hasopor Web page, http://www.hasopor.com/hasopor_intro/intro/english.html, accessed June 20, 2002

CATEGORY: Miscellaneous
CLASS: Glass Foam

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uses an estimated 53,000 tons of pumice annually, with material largely imported from Ecuador and Turkey. The glass recycling process is initially expected to consume about 40 tons of mixed color glass a month, increasing thereafter. The pilot project is expected to take four months, at which point the firm will be able to determine if the product can be commercialized.

In addition to the stone washing product, the firm is expecting to research other uses for foamed glass products for finishing, coatings removal and surface preparation and personal hygiene.

CONTACT: AMV, LLC, La Crosse, WI

REFERENCE: Recycling Technology Assistance Proposal of AMV, LLC, presented to Wisconsin Recycling Market Development Board, June 12, 1998

---CATEGORY: Miscellaneous
CLASS: Glass Foam

DESCRIPTION: The glass industry trade association in the UK, British Glass, looked at a variety of opportunities to recycle glass cullet, including glass foam blocks, calling it promising. Samples have been made and tested for strength and heat transfer and both showed good performance. To make foam blocks, cullet with a small addition of foaming agent is sintered under controlled conditions. The foam blocks were easy to handle and could be cut very accurately and easily with a hand saw.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256-258

CATEGORY: Miscellaneous
CLASS: Glass Foam

DESCRIPTION: A new firm, Earthstone, is being started in Atlanta to produce products out of foam glass. The firm expects to need between 100 and 6000 tons of cullet per month, and will use both mixed color and separated cullet. As of September 1996, the firm had not gone into production, but was still working on its product development.

CONTACT: Henry Oat, Earthstone, (505)473-3997; Steven Haines, earths@nets.com, ERFSTONE@aol.com

REFERENCE: Recycling Times, May 30, 1995, page 4; telephone conversation with Mr. Haines, September 11, 1996

CATEGORY: Miscellaneous
CLASS: Glass Polymer Composite Pipe

DESCRIPTION: San Jose State University looked at potential products to make out of recyclable glass, looking at products that would be high value, use a large volume of material, and be able to handle mixed color cullet. Three products were identified that could meet these criteria: sintered glass tile, water/wastewater filters, and glass polymer composite pipe.

The pipe was formulated with ABS plastic, and with both 0.5% glass and 1.25% glass, using both fine glass, and #12 mesh glass. It was found that the glass made the pipe very brittle, resulting in an unsuitable product.

CONTACT: Dr. Guna Selvaduray, San Jose State University, (408)924-3874

REFERENCE: Recycled Glass: Development of Market Potential. Final Report, Dr. Guna Selvaduray, Materials Engineering Department, San Jose State University for the City of San Jose, July 14, 1994, 45 pages

CATEGORY: Miscellaneous
CLASS: Golf Course Sand Traps

DESCRIPTION: Abilene, Texas has been using pulverized amber glass in golf course sand traps, where it is said to improve the drainage. It also has used this glass for road base, sand filter and pipe bedding applications.

CONTACT: The City of Abilene, Texas

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous
CLASS: Golf Course Sand Traps

DESCRIPTION: Broward County, FL is investigating the use of ground glass for a variety of purposes, including for golf course sand traps, as shot blast substitute for sandblasting, aggregate in glasphalt, etc.

CONTACT: Joseph Mather, Broward County, FL recycling coordinator, email address: recycle@bcfreenet.seflin.lib.fl.us

REFERENCE: Personal correspondence over the Internet, February 15, 1996

CATEGORY: Miscellaneous
CLASS: Hydraulic Cement

DESCRIPTION: Hydraulic cements of very high strength (up to 19,000 psi), low porosity, very rapid set times were developed by using glasses of CaO, SiO₂ and Al₂O₃ from a specified area on a ternary composition diagram of these three materials. Although previous work on hydraulic cements manufactured from glass did not produce a crystalline structure, this process does. To form the cement, the glass is melted together, cooled to a glass body, crushed to a powder passing a No. 200 sieve, and mixing with water on a water-to-powder ratio of about 0.4.

CONTACT: Corning Glass Works, Corning, NY

REFERENCE: Patent 4,605,443; 1986

CATEGORY: Miscellaneous
CLASS: Hydraulic Cement

DESCRIPTION: Using ground glass, it is possible to create a hydraulic cement with high mechanical strength, long term durability against attack by water, and freedom from creep. The composition of such cements can vary. One such formulation is (on a mole basis): 60-76% SiO₂, 15-30% K₂O, and 2-15% of a least one metal oxide from the following: 0-10% Al₂O₃, 0-5% V₂O₅, 0-5% TiO₂, 0-5% MoO₃, and 0-5% WO₃. To form the cement, the glass is melted together, cooled to a glass body, crushed to a powder passing a No. 100 sieve, and mixing with water on a powder-to-water ratio of between 1 to 2 and 4 to 1.

CONTACT: Corning Glass Works, Corning, NY

REFERENCE: Patent 4,440,576; 1984

CATEGORY: Miscellaneous
CLASS: Hydraulic Cement

DESCRIPTION: When ground into fine particles (passing 140 mesh screen, or less than 105 microns), glass powders can set up as strong cement if the glass powder has concentrations of 5% to 40% Na₂O/K₂O, 20% to 80% SiO₂, and 5% to 70% of a mixture of CaO (50% max), MgO (30% max), SrO or BaO (35% max). The cement is made by melting the glasses together, cooling to a glass body, crushing to a powder passing a 140 mesh screen, and mixing with water to a water-to-powder ratio of between 0.25 and 0.50. Setting time is from several to 60 days.

CONTACT: Corning Glass Works, Corning, NY

REFERENCE: Patent 3,743,525; 1973

CATEGORY: Miscellaneous
CLASS: Hydraulic Cement

DESCRIPTION: A fast setting (less than an hour) hydraulic cement can be produced from finely ground glass (less than 140 mesh or 105 microns) using a formulation of R₂O-SiO₂-P₂O₅, where R₂O is Na₂O and/or K₂O. The composition of the cement is 15-85% R₂O, 10-80% SiO₂ and 3-20% P₂O₅. The cement is made by melting the glasses together, cooling to a glass body, crushing to a powder passing a 140 mesh screen, and mixing with water to a water-to-powder ratio of between 0.25 and 0.50.

CONTACT: Corning Glass Works, Corning, NY

REFERENCE: Patents 3,720,527 and 3,720,527; 1973

CATEGORY: Miscellaneous
CLASS: Hydraulic Cement

DESCRIPTION: In this invention, it was found that finely ground glass (passing sieve No. 100) of approximately 80-94% SiO₂ and 20-6% Na₂O and/or K₂O (mol percent), when heated with steam, becomes both thermoplastic and an hydraulic cement. The glass absorbs water, and apparently the glass becomes a true solution in the water, with the water amounting to 30% on a weight basis. While the process works in the presence of other metal oxides, such as PbO, BaO, MgO, ZnO, B₂O₃, and Al₂O₃, it was found that the amount of SiO₂ plus Na₂O and/or K₂O should be at least 90% and the amount of CaO and Li₂O should be kept below 5 mol percent to avoid spontaneous crystallization and lack of steam reactivity.

CONTACT: Corning Glass Works, Corning, NY

REFERENCE: Patent 3,498,802; 1970

CATEGORY: Miscellaneous
CLASS: Hydroponic Growth Medium

DESCRIPTION: The Clean Washington Center has negotiated a contract to test the use of cullet as a hydroponic growth medium for the home, and possibly for use as a soil amendment, for pathways, xeriscaping, or aquarium gravel. It is believed that the density of the cullet will limit its use for large scale commercial operations. A report is expected by December 1995.

CONTACT: Bob Kirby, CWC, (206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995

CATEGORY: Miscellaneous
CLASS: Jewelry

DESCRIPTION: Several thousand tons of glass jewelry and sculpture have been sold under the label of Que Pasa.

CONTACT: Bruce Pizzichillo or Dari Gordon, (510)832-8380

REFERENCE: "Creating with Recycled Glass, BioCycle, February 1995, page 36

CATEGORY: Miscellaneous
CLASS: Jewelry

DESCRIPTION: White Light Productions of Exton, PA makes jewelry and art glass out of recycled glass bottles and antique glass. They have home pages on the World Wide Web at <http://www.voicenet.com/~markwlp/index.html> and at <http://www.ro.com/av/clientdata/cl1018.htm> [in cl1018, the second character is a small 'L']. The Web sites show color pictures of their products along with prices and order forms.

CONTACT: White Light Productions, 334 Penwyllt Court, Exton, PA 19341

REFERENCE: The above Web sites, June 4, 1996

CATEGORY: Miscellaneous
CLASS: Landscaping

DESCRIPTION: Albuquerque, NM is crushing and cleaning the mixed color glass from their recycling program, selling it for about \$15 a ton for landscape material.

CONTACT: City of Albuquerque, NM.

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous
CLASS: Landscaping

DESCRIPTION: The County of Maui in Hawaii has developed a number of alternatives to recycle glass, including its use as sandblasting material, in landscape decoration and as a 10% additive to base chords of roads.

CONTACT: County of Maui, Hawaii

REFERENCE: "From Hero to Bum in Less than a Heartbeat", Jack Beardwood, MSW Management, July/August 2002, pages 68-72

CATEGORY: Miscellaneous
CLASS: Landscaping

DESCRIPTION: In Scottsdale, AZ, the city is working with a private firm (Enviro Sand, Inc.) to grind glass bottles into six different sizes, including marble size pieces for landscaping as well as art objects, sand for use in ashtrays and construction projects, and chalk for painting lines on baseball fields.

CONTACT: Dennis Enriquez, City of Scottsdale environmental coordinator, Dave Columb, President, Enviro Sand Inc.

REFERENCE: "Glass Breads Into Pebbles in Ariz.", Bruce Geiselman, Waste News, June 8, 1998, page 17

--- CATEGORY: Miscellaneous
CLASS: Landscaping

DESCRIPTION: In Hawaii, processed cullet is being used for landscaping purposes.

CONTACT: Thomas Reed, Aloha Recycling Technologies, Kihei, HI, (808)875-2520

REFERENCE: Personal communication from Andela Tool & Machine Co., August 1995

CATEGORY: Miscellaneous
CLASS: Marbles

DESCRIPTION: In Michigan, the Lucky Dog company manufactures marbles out of 50% post-consumer and 50% pre-consumer glass cullet.

CONTACT: Charlie Hall, Lucky Dog Enterprises, PO Box 87, Chesaning, MI 48616-0087, (517)845-2632

REFERENCE: Michigan Manufactured Recycled Products, Michigan Department of Environmental Quality, page 49, 1995

CATEGORY: Miscellaneous
CLASS: Railway Ballast

DESCRIPTION: In England, the trade association for glass has identified a number of alternative potential uses for glass cullet, including railway ballast. However, they are not aware of any in-depth studies into this potential use.

CONTACT: British Glass Manufacturers Confederation, Northumberland Road, Sheffield, South Yorkshire S10 2UA, UK, fax 0114 268 1073

REFERENCE: "Alternative Uses for Cullet", Stan Bedford, Glass, July 1994, pages 256-258

CATEGORY: Miscellaneous
CLASS: Railway Traction

DESCRIPTION: Railroad locomotives can spread sand on the railroad tracks in slippery conditions, and in Kansas, a researcher is exploring the use of crushed glass in place of the sand.

CONTACT: Unknown

REFERENCE: Telephone conversation with Ms. Chiquita Cornelius, Kansas Business-Industry Recycling Program, (913)273-6808, November 26, 1996

CATEGORY: Miscellaneous
CLASS: Reflective Beads

DESCRIPTION: When ground into sub-micron size, all three colors of glass cullet can be used in reflective paint, according to research done at the "Missouri Enterprise" group at the University of Missouri-Rolla. The project used a pebble ball mill, which is equipment used in the mining industry to grind the glass to 50-mesh size, about the consistency of talcum powder. The researchers also added titanium to make the paint more reflective. The net result is a paint that 10 cents per gallon less expensive than normal reflective paint. The first application for the paint is scheduled for April, 1993.

CONTACT: Dennis Roedemeier, Executive Director, Missouri Enterprise, University of Missouri-Rolla

REFERENCE: Recycling Times, April 6, 1993, page 6

CATEGORY: Miscellaneous
CLASS: Reflective Beads

DESCRIPTION: The State of New Jersey has a bid specification for the purchase of glass beads to be used in reflective paint by the NJ Department of Transportation for use in reflective traffic paint. (While there is no requirement or restriction on the use of recycled glass, the use of recycled glass is common for the manufacture of glass beads.)

A summary of the specifications include the following:

1. At least 70% of the beads are to be spherical
2. Gradation shall be as follows:

| Sieve Size | |
|------------|--------|
| < No. 16 | 0% |
| No. 16-20 | 0-2% |
| No. 20-30 | 5-28% |
| No. 30-50 | 35-65% |
| No. 50-100 | 15-40% |
| > No. 100 | 0-5% |

3. Index of refraction of 1.50-1.65.
4. Chemically stable to atmospheric conditions, moisture, dilute acids, dilute alkalis and paint.
5. Packaged in 50 lb bags.

The specification describes ASTM or other tests to show compliance with these requirements.

CONTACT: State of New Jersey Division of Purchase and Property, Purchase Bureau, 135 W. Hanover Street, Trenton, NJ 08625

REFERENCE: NJ Specification from National Association of State Purchasing Officials BBS, October 21, 1993

CATEGORY: Miscellaneous
CLASS: Reflective Beads

DESCRIPTION: Vitreous Environmental Group is building a glass container processing plant in Calgary, Alberta to produce material used for fiberglass, paint and golf course maintenance products.

CONTACT: Vitreous Environmental Group, PO Box 3202, Airdrie, Alberta, T4B 2B5, Canada, (403)948-7811

REFERENCE: Resource Recycling, May 1994, page 77

CATEGORY: Miscellaneous
CLASS: Reflective Beads

DESCRIPTION: The Wisconsin Department of Transportation uses glass beads made from recycled glass in reflective pavement paints. In 1992, approximately 2 million pounds of glass beads were used, while in 1994, 3 million pounds were used. [Compiler's note: it is not stated if the glass was bottle glass, plate glass or some other type of glass.]

CONTACT: Steve Shoberg, Wisconsin Department of Transportation, 4802 Sheboygan Avenue, Madison, WI 53702, (608)266-2836

REFERENCE: Presentation by Steve Tobago to the Wisconsin Council on Recycling, April 19, 1993; Report on State Agency Resource Recovery & Recycling Program, Wisconsin Department of Administration, March 1, 1995

CATEGORY: Miscellaneous
CLASS: Reflective Beads

DESCRIPTION: For the 1996 season, the Dane County, WI Highway and Transportation Department purchased 280,000 pounds of glass beads for use as a reflective medium for highway painting. The beads are sprayed onto the highway stripes just after the stripes are painted. The beads were purchased off the state of Wisconsin contract from Flex-O-Lite of St. Louis, MO at a cost of \$0.1879 per pound, and have a gradation as follows:

| Sieve | % Passing |
|-------|-----------|
| 20 | 95-100 |
| 30 | 70-90 |
| 50 | 10-30 |
| 80 | 0-2 |
| 100 | 0-1 |

CONTACT: Pamela Dunphy, Assistant Commissioner, Dane County Highway and Transportation Department, 2302 Fish Hatchery Road, Madison, WI 53713, (608)266-4261

REFERENCE: Personal communication with Highway Department staff May 13, 1996, and order letter dated March 5, 1996

CATEGORY: Miscellaneous
CLASS: Road Traction

DESCRIPTION: A experiment was being planned to use crushed glass as a substitute for road sand in the winter.

CONTACT: Jack Sargent, Warren County Highway, 408 W. Washington, Williamsport, IN 47993, (317)762-6181

REFERENCE: Telephone call from Mr. Sargent, February 11, 1993

CATEGORY: Miscellaneous
CLASS: Road Traction

DESCRIPTION: In Canada, 1,100 tons of mixed-color cullet will be used by Quebec for road traction material in the winter.

In an undated brochure from Environmental Sands, Inc., it was stated that Quebec used ground-up cullet as a substitute for sand, and that the cullet worked as well as the sand.

CONTACT: unknown

REFERENCE: Resource Recycling, January 1994, page 66; brochure of Environmental Sands, Inc., no date (1995?), (612)898-1350

CATEGORY: Miscellaneous
CLASS: Road Traction

DESCRIPTION: Python's Recycling Center in St. Cloud, MN used ground-up glass cullet as a traction material at their load docks and found it to be suitable.

CONTACT: Unknown

REFERENCE: Undated (1995?) brochure of Environmental Sands, Inc., (612)898-1350

CATEGORY: Miscellaneous
CLASS: Road Traction

DESCRIPTION: The Hunts Point recycling center in New York City is crushing glass with an Andela pulverizer, and, besides using the cullet for glasphalt, the use as a road traction material is also being investigated. It is noted that the glass does not have sharp edges and is comparable to sand used in a child's sandbox.

CONTACT: Mike Mongelli, Operation Manger, Hunts Point Recycling, New York, NY; Vito LaCreca, Automated Waste and Recycling Systems, (718)444-5706 or Cynthia Andela, Andela Tool & Machine, Inc., (315)858-0055

REFERENCE: Article reprinted from Waste Handling Equipment News, provided by Andela Tool & Machine, Inc., fall 1995

CATEGORY: Miscellaneous
CLASS: Road Traction

DESCRIPTION: The Grand Canyon National Park is crushing up the glass it collects for recycling and using it for a variety of purposes, including for road and path traction at building entrances and exits where it can be swept up in the spring.

CONTACT: Grand Canyon National Park, Arizona

REFERENCE: "Grand Canyon, Arizona. Recycled Glass Finds Home in National Park", BioCycle, September 2001, page 19

CATEGORY: Miscellaneous
CLASS: Roof Coating

DESCRIPTION: Finely crushed (200 mesh) grade glass is being tested as a silica filler roof coatings, and more generically, as polymer fillers. So far, this material appears to be working well; final results are expected in September, 1995.

CONTACT: Bob Kirby, CWC, (206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995

CATEGORY: Miscellaneous
CLASS: Roof Coating

DESCRIPTION: Eco Coatings of Seattle is using finely ground container cullet as a filler in elastomeric roof coating systems. The coating material is used to seal concrete, concrete block, masonry and stucco surfaces.

CONTACT: Eco Coatings, Seattle, WA

REFERENCE: Resource Recycling, February 1997, page 59

CATEGORY: Miscellaneous
CLASS: Sanding Material

DESCRIPTION: Earthstone International has developed a sanding block using recycled material. Said to be clog-resistant, the sanding blocks are available in a variety of consistencies suitable for wood, drywall or metal. The company is developing a material that would be usable for cleaning food and grease from cooking surfaces, such as backyard grills.

CONTACT: Earthstone International, Santa Fe, New Mexico

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous
CLASS: Septic Tank Treatment Systems

DESCRIPTION: The Clean Washington Center is sponsoring a study of the use of cullet as a substitute for C-33 cement sand in intermittent sand septic treatment systems. A 12-month study of two full-scale residential installations was completed in the spring of 1995. The cullet worked well; the higher permeability of the glass as compared to sand, and the lack of colloidal solids in the glass resulted in less of a clogging problem of the media than what is experienced with sand and may mean that system using glass could be smaller amount than the equivalent system with sand. However, a researcher notes that with sand, there is a biomat formed on the sand which provides some of the treatment of the effluent, while the glass has less of a tendency to form the biomat. As a result, the glass filter has more varied results on the treatment of fecal coliform. Another year of testing is to be done to obtain better data.

CONTACT: Bob Kirby, CWC, (206)443-7746, fax (206)464-6902, email kirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995; Recycling Times, August 8, 1995, page 6

CATEGORY: Miscellaneous
CLASS: Septic Tank Treatment Systems

DESCRIPTION: The State of Alaska is working with the City of Anchorage and the Anchorage Recycling Center to use glass cullet as a filtration material in septic tank construction. Pilot projects will be constructed in the summer of 1996.

CONTACT: David Wigglesworth, Chief, Pollution Prevention Office, (907)269-7586

REFERENCE: Personal correspondence from Lisa Rozmyn, Pollution Prevention Specialist, Alaska Department of Environmental Conservation, January 30, 1996

CATEGORY: Miscellaneous
CLASS: Septic Tank Treatment Systems

DESCRIPTION: The Town of Dryden, Ontario is negotiating with the province to use cullet as a drainage aggregate in septic filed construction.

In addition, the town uses cullet for drainage aggregate in trench drains and in French drains in parkland and residential subdivision work. The Town has also provided cullet to the private sector for use over weeping tile in new house construction. Finally, the town uses cullet as base aggregate in road construction, mixed at 10% or less with pit run gravel.

CONTACT: M. Fisher, Town of Dryden, 30 Van Horne Avenue, Dryden, ON P8N 2A7, (807)223-2367

REFERENCE: Personal letter from M. Fisher, May 13, 1996

CATEGORY: Miscellaneous
CLASS: Steel Production

DESCRIPTION: Oregon Steel, in Portland, OR is using scrap green glass to provide silica needed to make steel.

CONTACT: unknown

REFERENCE: Resource Recycling, April 1994, page 110

CATEGORY: Miscellaneous
CLASS: Stone

DESCRIPTION: TriVitro of Kent, Washington is making a decorative stone for fishbowls, floral displays, mosaic glass and similar uses from tumbled glass.

CONTACT: TriVitro, Kent, WA, <http://www.trivitro.com/> (accessed January 24, 2003)

REFERENCE: "Breaking Glass Markets", Jerry Powell, Resource Recycling, September 2002, pages 10-13

CATEGORY: Miscellaneous
CLASS: Stone

DESCRIPTION: Great Harbor Design Center in Queens, New York will begin to make stone panels from container glass beginning in June, 2000. The stone is 1 inch thick and will be sold through Home Depot and possibly other outlets.

CONTACT: Tim McCarthy, CEO, Great Harbor Design Center, New York, NY

REFERENCE: "Harboring Hope for Recycling", Waste News, page 40, June 12, 2000

CATEGORY: Miscellaneous
CLASS: Stonewash Abrasive

DESCRIPTION: AMV, LLC of La Crosse, WI has received funding from the Wisconsin Recycling Market Development Board to produce an foamed glass abrasive made of recycled glass for use in the stone washing industry, such as for washing denim jeans. Currently, the stone washing industry uses an estimated 53,000 tons of pumice annually, with material largely imported from Ecuador and Turkey. The glass recycling process is initially expected to consume about 40 tons of mixed color glass a month, increasing thereafter. The pilot project is expected to take four months, at which point the firm will be able to determine if the product can be commercialized.

In addition to the stone washing product, the firm is expecting to research other uses for foamed glass products for finishing, coatings removal and surface preparation and personal hygiene.

CONTACT: AMV, LLC, La Crosse, WI

REFERENCE: Recycling Technology Assistance Proposal of AMV, LLC, presented to Wisconsin Recycling Market Development Board, June 12, 1998

--- CATEGORY: Miscellaneous
CLASS: Tableware

DESCRIPTION: Green Glass USA LLC is building a plant in Stratford, WI to make drinking glasses out of various types of bottles. The firm has operated in South Africa since 1992, and their product is said to be selling well in both Africa and Europe. The US plant is expected to open in August, 2000 and will initially process 65,000 bottles a month, increasing to 200,000 bottles a month within 3 years. The company will pay 20¢ per reusable bottle.

CONTACT: Not given

REFERENCE: "S. African Company Reuses Entire Bottle", Waste News, October 18, 1999, page 24; "Drink to Recycling", Waste Age, June 2000, page 36

CATEGORY: Miscellaneous
CLASS: Tableware

DESCRIPTION: Green Glass, which makes drinking glasses from glass bottles, has a web page of their products at <http://www.greenglass.com>

CONTACT: Arthur Jackson, Green Glass USA, PO Box 1040, Great Barrington, MA 01230 , (413) 274-1111, FAX (413) 274-1112 , email: arthur@greenglass.com

REFERENCE: Web page, October 20, 1999

---CATEGORY: Miscellaneous
CLASS: Tableware

DESCRIPTION: Fire & Light, an Arcata, CA firm, has been making bowls and plates from bottle cullet since 1995 and now has 500 customers. It has 10 employees, and sold over 50,000 pieces of tableware last year, equivalent to about 75 tons of glass. In 1998, production is expected to increase, averaging about 3,000 pounds a day.

CONTACT: Micki Flatmo, Fire & Light, Arcata, CA, Margaret Gainer, Gainer & Associates, (707)822-8347

REFERENCE: "Start-Up Creates Local Loop for Recycled Glass", BioCycle, March 1998, pages 54-57

--CATEGORY: Miscellaneous
CLASS: Tableware

DESCRIPTION: A small Mexican company is making blown glass tableware using 100% scrap glass, producing 3200-3500 pieces per day, exporting 90%. Because of high demand, the company is looking at expanding production.

CONTACT: unknown

REFERENCE: Reiterate, the Newsletter of the Recycling Council of British Columbia, February 1992, page 13, from Warmer Bulletin, November 1991

CATEGORY: Miscellaneous
CLASS: Traction

DESCRIPTION: Anti-slip material for ramps, walkways and decks is made from portland cement, epoxy and recycled glass, with up to 70% post-consumer glass.

CONTACT: Castle Rock Industrial Floor Co., Inc., 4925 N Pearl, #C, Tacoma, WA 98407, (206)752-6166

REFERENCE: The Harris Directory, The Stafford Architects, October 1994

CATEGORY: Miscellaneous
CLASS: Waste Water Filter

DESCRIPTION: A water park in Lubbock, Texas tested the use of glass in a water filter in comparison to a sand filter. Their preliminary conclusions were that the glass removed more contaminants from the water, was cleaned quicker when backflushed and used 60% less electricity to operate. More detailed analyses were to be done later in the year, after the water park closed for the year.

CONTACT: Texas Water Rampage, Lubbock, TX

REFERENCE: "Preliminary Report. Sand Filter Media: Glass vs. Sand", Texas Water Rampage, Lubbock, TX, July 7, 1997, 4 pages

CATEGORY: Miscellaneous
CLASS: Waste Water Filter

DESCRIPTION: The Town of Oswego, NY has constructed a recirculating granular media filter to treat 151,000 gallons per day of domestic waste water, and has finished with its evaluation, concluding that it worked well as an alternative to natural or processed sand. The cost of the material was also \$12.50 a ton less expensive than natural sand used in the area.

CONTACT: Town of Oswego, NY or Nexcycle Resources, Inc., Mattydale, NY

REFERENCE: "Crushed Recycled Glass Filter Media", BioCycle, September 2001, page 80, "Oswego, New York. Crushed Recycled Glass Evaluated in Recirculating Filter", BioCycle, October 2001, page 18

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: Crushed glass was used as a filtering medium in a dual-media pressure filter with anthracite and compared to a dual filter of anthracite and sand. The particle removal of the glass was slightly poorer than the particle removal of the sand. Startup of the glass filter was more variable than the sand and appeared to improve as the glass began to wear. Minimal processing was done of the glass used in the filter and the researchers believe that further work to improve the efficiency of glass in filters and examining the market application is critical.

CONTACT: Journal of Environmental Engineering and Science, http://pubs.nrc-cnrc.gc.ca/cgi-bin/rp/rp2_tocs_e?jees_jees5-02_1

REFERENCE: ""Comparing Crushed Recycled Glass to Silica Sand for Dual Media Filtration", Simon O. Rutledge and Graham A. Gagnon, Journal of Environmental Engineering and Science, Vol 1, No. 5, September 2002, pages 349-358, accessed on the Internet on July 9, 2003.

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: A Scottish firm received funding from the European Commission in 2002 to help develop the use of glass cullet for filtering drinking water. For several years, the firm has marketing a glass cullet filtering media for fish farming and swimming pool filters.

CONTACT: Dryden Aqua Limited, Midlothian, Scotland, <http://www.drydenaqua.com/>

REFERENCE: "LIFE-Environment: Commission Grants €69 Million for 109 Environmental Innovation Projects", on the Internet at http://europa.eu.int/comm/environment/life/news/life-env_press02.htm and "WRAP. Creating Markets for Recycled Resources. Achievements Report 2001/2002" http://www.wrap.org.uk/publications/Wrap_achievements_2001to2002.pdf, both accessed on November 5, 2002

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: A water park in Lubbock, Texas tested the use of glass in a water filter in comparison to a sand filter. Their preliminary conclusions were that the glass removed more contaminants from the water, was cleaned quicker when backflushed and used 60% less electricity to operate. More detailed analyses were to be done later in the year, after the water park closed for the year.

CONTACT: Texas Water Rampage, Lubbock, TX

REFERENCE: "Preliminary Report. Sand Filter Media: Glass vs. Sand", Texas Water Rampage, Lubbock, TX, July 7, 1997, 4 pages

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: Pulverized glass was found to be an effective alternative to silica sand as a filter media for slow sand filtration, according to a study done for the Clean Washington Center. The report cautions that the results are not necessarily transferable to other water treatment systems.

CONTACT: Internet, <http://www.cwc.org/glass/gl954rpt.pdf>, or the National Technical Information Service, 5285 Port Royal Road, Springfield, V 22161, (800)553-6847, <http://www.ntis.fedword.gov>, report PB98-158959WEP

REFERENCE: "Examination of Pulverized Waste Recycled Glass as Filter Media in Slow Sand Filtration", Gray & Osborne, Inc., 1995, 42 pages, on the Internet at <http://www.cwc.org/glass/gl954rpt.pdf>, accessed July 9, 2003

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: The Clean Washington Center is sponsoring bench flow tests of cullet and five types of sand for a slow sand water treatment system to be installed in a municipal water treatment system in central Washington. The tests are to end in March 1995, with a report available in May 1995. This project builds upon previous work done at San Jose State University on the use of glass as a water filtration medium. Performance to date looks good, although the cullet may not be the best filtration medium. Also, because of the volume of medium needed, the use of cullet may not be practical. However, the results, if favorable, may lead to the use of cullet for smaller scale systems, such as for swimming pools, aquariums, etc.

CONTACT: Bob Kirby, CWC, (206)587-5520, emailkirbgood@aol.com

REFERENCE: Personal correspondence from Bob Kirby, March 6, 1995

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: Faculty at Syracuse University in New York have received state financial assistance to test the use of glass cullet produced by an Andela glass crusher in a "slow sand" filter for water treatment.

The project is expected to be complete by May 1996.

CONTACT: Professor Letterman, Syracuse University, Syracuse, NY

REFERENCE: Personal phone conversation with Cynthia Andela, Andela Tool & Machine, Inc., Richfield Springs, NY, May 23, 1995; "Better Recycling Through Engineering", Civil and Environmental Engineering SURvey, Syracuse University, Fall 1995, page 2

CATEGORY: Miscellaneous
CLASS: Water Filter

DESCRIPTION: San Jose State University looked at potential products to make out of recyclable glass, looking at products that would be high value, use a large volume of material, and be able to handle mixed color cullet. Three products were identified that could meet these criteria: sintered glass tile, water/wastewater filters, and glass polymer composite pipe.

Glass was tested as a water filter in three sizes -- 40 mesh, 50 mesh and 60 mesh. Filtration columns were set up for each material along with a control column using sand, and the materials were tested for their efficiency in removing turbidity and for there backwash characteristics.

The glass was far superior to the sand in removing turbidity, removing 93% of the turbidity compared to 71% for the sand. The glass also achieved its efficiency much quicker than the sand -- 6 minutes versus 12 minutes for sand. For backwashing, the 50 and 60 mesh glass took slightly longer to wash than the sand, while the 40 mesh glass had a shorter backwash time. Each of the glass filters had a somewhat larger expanded depth than the sand.

Economically, it appeared that the glass would be a more expensive medium than sand on a ton for ton basis; the effect of increased efficiency and hence a possibly smaller filter bed was not studied.

CONTACT: Dr. Guna Selvaduray, San Jose State University, (408)924-3874

REFERENCE: Recycled Glass: Development of Market Potential. Final Report, Dr. Guna Selvaduray, Materials Engineering Department, San Jose State University for the City of San Jose, July 14, 1994, 45 pages

---CATEGORY: Miscellaneous

CLASS: Water Filter

DESCRIPTION: Food grade glass bottles are used to make electromagnetized waste water filters that are used in projects ranging from sewage treatment to home swimming pools.

CONTACT: Johnson Waste Water Filter Company, Aurora, Illinois

REFERENCE: The Minnesota Project, July 1992, Waste Age, September 1991, page 31
