FINAL REPORT
SEDIMENT MELTER
DEMONSTRATION PROJECT

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INTRODUCTION

The presence of PCBs in the lower Fox River in northeastern Wisconsin has been a concern for many years. Extensive investigations of the river bottom have taken place during the 1980s and 1990s. Two areas of the river have undergone demonstration dredging in the past five years.

While planning the appropriate remedial response to be undertaken, the Wisconsin Department of Natural Resources (DNR) requested input from the public. Minergy proposed a feasibility study to determine the potential to use a glass furnace capable of melting the contaminated river sediment at high temperature, thereby destroying the PCBs and binding any metals in the glass aggregate produced. Such furnaces have been used for decades to make glass. Feedstock consisting primarily of silica sand (which is the main constituent of river sediment) melts in the furnace. The molten product is cooled to form glass aggregate, which is a marketable construction material.

This report is written to summarize the activities undertaken during Phase 3 of the multi-phase glass furnace feasibility study. The first two phases of the feasibility study determined that the minerals contained in dredged sediments could form a stable glass, and that the variability of mineral concentrations along the lower Fox River appeared to be within acceptable ranges. Results from these phases are available in reports sent to the Department under separate cover.

During one of the demonstration dredging projects, the DNR containerized approximately 60 tons of de-watered, contaminated river sediment. The DNR contracted with Minergy for the design, construction, and operation of a pilot melter, to melt the sediment into a glass aggregate.

Sediment Loading into Containers

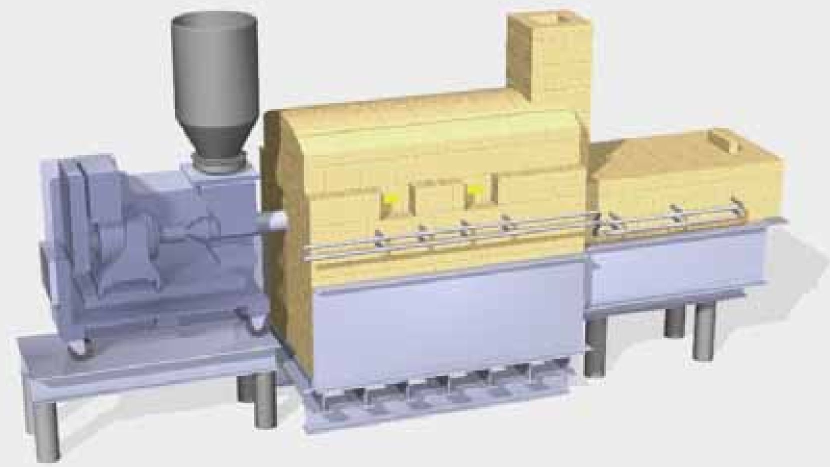
The U.S. EPA Superfund Innovative Technology Evaluation (SITE) program was used to perform an independent evaluation of the fate of PCB and other contaminants for Phase III. The dryer segment of the analysis was performed at the Hazen Research, Inc. facility in Golden, Colorado in January 2001. At that location, Hazen has a demonstration-scale dryer of the appropriate technology for use on sediments.

Sediment Melter

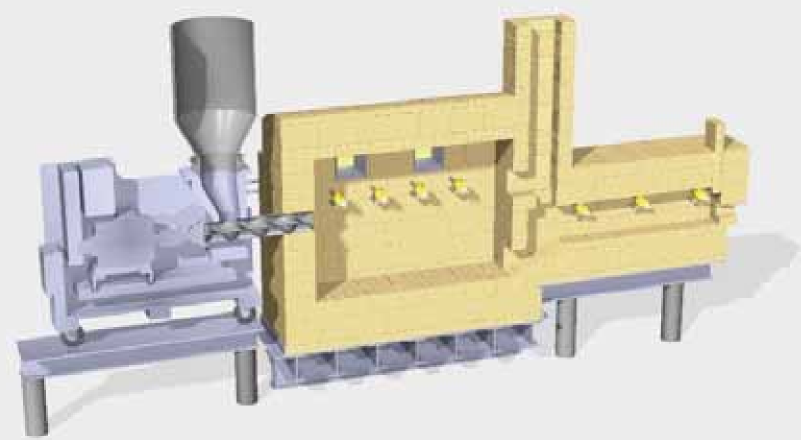
The melter evaluation was performed at Minergy's GlassPack Test Center in Winneconne, Wisconsin. A demonstration-scale melter was constructed, with operation of the melter from May to August, 2001. The pilot program was designed to confirm that the technology can destroy PCB contamination, stabilize trace metals, and convert the mineral content of river sediment into an inert, marketable construction material.

Under SITE program, the fate of PCBs and other compounds within the river sediment were monitored during the processing and melting of the river sediment. The SITE program test results will be submitted under separate cover by the EPA contractors responsible for gathering that data.

GLASS FURNACE TECHNOLOGY DESCRIPTION



External view of sediment melter



Internal view of empty melter with oxy-fuel burners in place (warm-up condition).

Introduction to Glass Furnaces

A Glass Furnace is a refractory-lined, rectangular melter.

Refractory is brick or concrete which has been specially treated to resist chemical and physical abrasion, has a high melting point, and provides a high degree of insulating value to the process.

Current glass furnaces use oxy-fuel burners, combining natural gas and oxygen for a bright flame above the glass. These burners raise the internal temperature of the melter to 2900 degrees Fahrenheit.

At these high temperatures, PCB contaminants are destroyed, and the sediment melts and flows out of the processing system as molten glass.

Melter Process Description

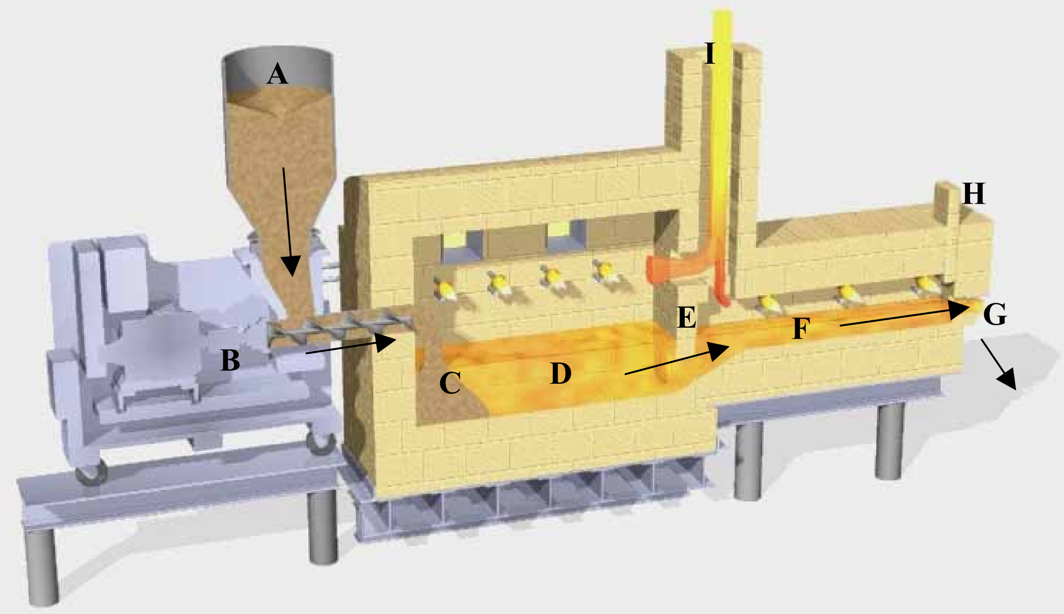


Fig 3. Internal view of melter (sediment feeding and melting)

Sediment (A) is fed to the hopper above the screw feeder (B). The feeder conveys the sediment continuously into the main section of the melter (C). The extremely high temperatures in the melter cause the sediment to become molten, liquid glass (D). The molten glass flows under a skimmer block (E), into the forehearth (F), where the material continues to form a stable glass. At the end of the melter, the glass flows out (G) into a water quenching tank. A removable block is included at the end of the forehearth (H) to stop the flow of glass if desired. Exhaust gases (I) flow out from the furnace up the square flue, to the air quality control equipment.

RIVER SEDIMENT MINERAL STUDY BY WDNR/MINERGY

Phase I of the feasibility study characterized the mineral composition of river sediments to estimate the glass quality, durability and melting points. Phase I conclusions include that river sediment characteristics are consistent throughout the river and are favorable for producing a quality glass product. Further, vitrification technology is more appropriate for river sediments than incineration as demonstrated by the low Loss on Ignition analyses.

River Mineralogy Study

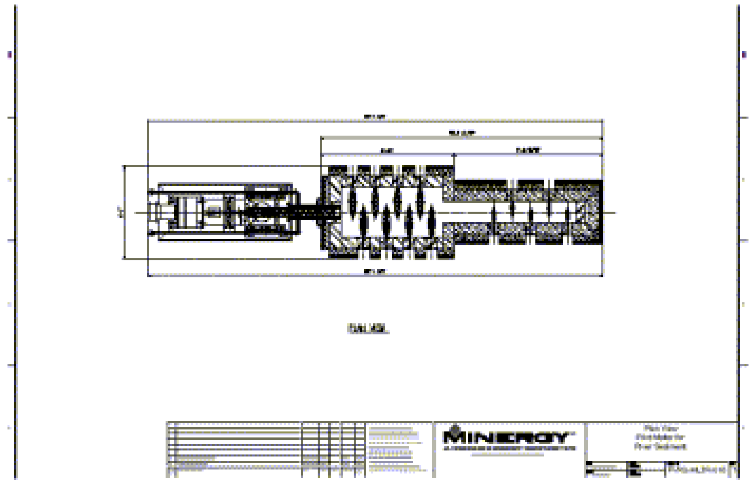
Date Collected	1/5/99	Nov. 11	Nov. 11	9/28/95	9/30/95	10/3/95	10/4/95	10/5/95	10/7/95	10/12/95	6/3/98	6/3/98	6/5/98	6/5/98	6/5/98	6/5/98
Lab #		A	B	5297	5300	5290	5299	5298	5289	5291	5295	5296	5292	5293	5294	5301
Al2O3	10.70	5.03	4.53	9.03	14.10	10.20	14.70	14.20	11.80	10.60	13.80	13.20	11.80	12.80	13.70	11.20
SiO2	63.70	76.90	80.50	80.50	63.10	58.90	59.20	62.10	58.30	65.80	62.30	58.40	53.30	62.10	61.10	53.50
CaO	7.91	8.10	5.17	1.04	7.29	9.84	9.07	7.15	10.40	8.09	7.22	9.93	15.90	7.88	7.75	11.00
Fe2O3	4.58	1.90	1.32	3.19	5.84	3.62	6.00	5.55	4.66	3.73	6.45	5.40	5.29	5.49	5.35	4.61
TiO2	0.55	0.10	0.07	0.37	0.61	0.54	1.17	0.80	0.71	0.53	0.65	0.89	0.63	0.68	0.68	0.67
Na2O	0.98	0.88	0.73	0.90	0.52	0.77	0.61	0.71	0.70	0.74	0.56	0.71	0.71	0.74	0.69	0.65
MgO	6.09	4.58	3.87	1.46	6.28	8.16	6.70	6.86	6.53	5.66	6.81	7.92	4.56	7.17	7.96	8.80
P2O5	0.22	0.08	0.08	0.10	0.32	0.41	0.72	0.38	0.37	0.30	0.34	0.48	0.30	0.26	0.33	0.40
S	0.48	0.33	0.26	<0.05	0.41	0.66	0.56	0.36	0.52	0.35	0.48	0.69	0.35	0.27	0.27	0.56
Cl	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	0.03	<0.02	0.02	<0.02	<0.02	0.03	<0.02	<0.02	<0.02	0.03
K2O	3.48	2.04	2.16	2.87	2.95	2.92	3.23	3.55	3.11	3.17	2.97	3.16	2.99	3.53	3.65	2.99
MnO	0.07	0.02	0.02	0.04	0.07	0.05	0.08	0.06	0.07	0.06	0.07	0.07	0.07	0.06	0.06	0.07
BaO	0.06	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.03

Phase II of the project, crucible melts of actual Lower Fox River sediment, were conducted to determine the actual melting conditions and glass characteristics/qualities of the sediment alone and when augmented with other materials (flux mixtures). Four different test “recipes” were included in the crucible melts and the sediment successfully melted into glass in all four tests. Phase II results include a proposed recipe for melting river sediment into glass aggregate and preliminary engineering designs for the pilot test facility proposed for Phase III. This preliminary engineering recommended

Melt #	Flux utilized	Viscosity	Glass Pouring
1	None	High	Sticky
2	Sodium carbonate	Low	Flowed
3	Dolomitic limestone	Very Low	Flowed
4	3-mix cullet	Medium	Flowed

Crucible Melt Results

not to use an existing glass furnace for Phase III testing. Results of Phase II engineering indicated that the cost to retrofit an existing facility for the purposes of a limited-term test would be as much as building a new pilot melter to those same specifications. Also, most existing facilities were far too large to accommodate a limited duration test.



Melter Preliminary Engineering

U.S. EPA Air Testing

Feasibility Study Phase III

The third phase of the feasibility study was broken into two segments, one to evaluate the sediment dryer and another to evaluate the sediment melter. The U.S. EPA Superfund Innovative Technology Evaluation program was used to perform an independent evaluation of the fate of PCB and other contaminants for both segments. The dryer segment was performed in Golden, Colorado, at the Hazen Research laboratory, where a demonstration-scale dryer of the appropriate technology for use on sediments was already in existence. The melter segment was performed at Minergy's GlassPack Test Center in Winneconne, Wisconsin.

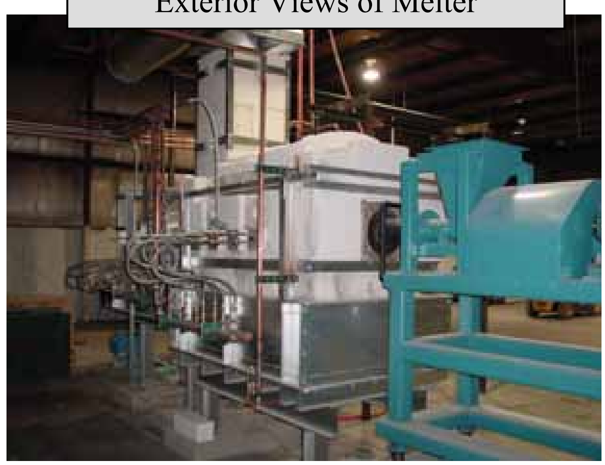
MELTER DESIGN

The pilot melter is designed to simulate a full-scale production melter for the generation of glass aggregate from sediments. In order to adequately produce a model, some assumptions have been made with regard to the full-scale melter in accordance with typical glass operating practices. The pilot melter is scaled down from the full-scale melter and has been designed to operate in a manner which would suggest design features for most major elements of the full scale melter.

Pilot Melter Characteristics

Aspect Ratio	2:1
Area	10 sq ft.
Melting Rate	5.4 $ft.^2$/ton
Dwell Time	6 hrs.
Gas Usage	1.7 MM Btu/hr.
Oxygen Usage	35 ccfh
MM Btu/Ton	20.9 mmbtu/ton
Output	2 tons/day

Exterior Views of Melter



Minergy has intellectual property protection for the application of glass furnace technology on contaminated sediments. Several modifications to the standard melter design have been incorporated to best suit this application. These modifications include:


Molten Glass in Quench Tank

- The use of a water quench system to quickly harden the molten glass and increase the inert characteristics of the final product. Glass melters typically use annealing or other slow-cooling products to enhance glass clarity and other product qualities. These product features are not significant in the manufacture of glass aggregate because its final use is as a construction product where glass clarity is not necessary. Determination of the leaching characteristics of the final product will be done as part of the S.I.T.E. investigation. Molten material is drained from the end of the melter into the water-filled quench tank. An inclined ¼-inch steel plate, cooled by a constant water stream, directs falling liquid aggregate into the hopper of an auger submerged in the quench tank. The auger moves the aggregate out of the quench tank into barrels.


Aggregate Screw Conveyor

- The pilot melter is 10 square feet with a 2:1 aspect ratio. The materials selected are typical for soda-lime glass operations in an oxy-fuel environment. Six inches of extra sidewall has been added to the height to accommodate organics contained in the sediment feedstock.
- The melter will have eight Split-Stream oxy-fuel burners to approximate the burners that would be used in a full-scale melter.

Top View of Melter

Flue Coupled to Outlet Duct

- The melter is oxy-fuel fired to utilize the B.A.C.T. for NO_X emissions and reduced particulate. The glass quality is adequate with 6 hours of dwell time, so it runs a shallow glass level.
- The flue is located in the front of the melter, which is not the traditional location for oxy-fuel furnaces. This is done so that any fine particulate that becomes entrapped into the exhaust gases will have the maximum time in the furnace to allow these particulates to be melted, or minimized.

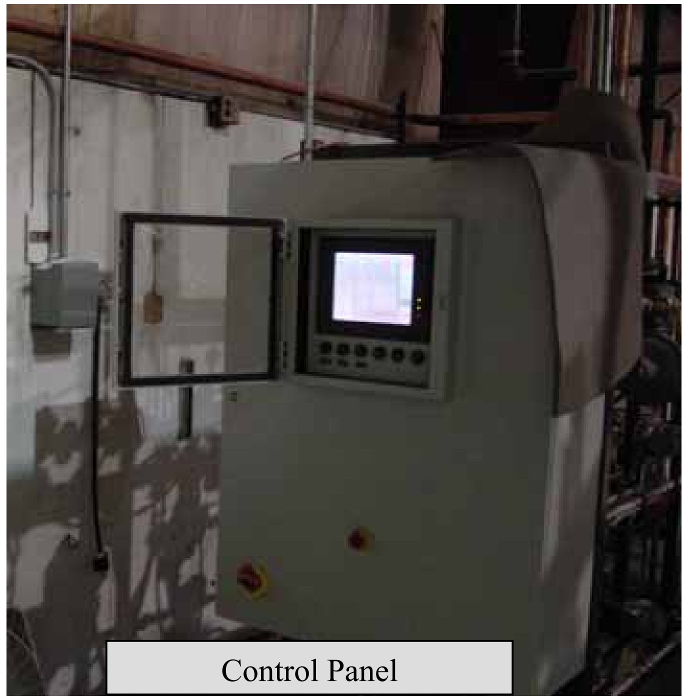
- Sediment is fed in on one end of the melter through a water-cooled screw charger. The charger is a standard screw batch charger that has been used all over the world for charging batch in glass furnaces. The screw charger was chosen due to the ability to tightly seal the charging hopper to the charger and the charger to the furnace. This minimizes dusting of the raw material feedstock. The charger is similar in size to that which would be used in a full-scale unit. It has been retrofitted with a small screw barrel and flights for the pilot melter. This charger can be reused for a full-scale melter by modifying the barrel and flights. A variable-speed drive allows control of the feed rate.

Sediment Screw Charger

Air Filtration on Sediment Hopper

- Negative pressure is placed on the feed hopper during charging operations to control dust.
- The melter design capacity is 2 tons per day or 170 pounds of river sediment per hour. The sediment bags weighed approximately 50 gross pounds, so the feed rate was expected to be between four and five bags per hour.

- The pilot melter is controlled by control loops to the melter and forehearth. The control loops use thermocouple signals to maintain a constant temperature by automatically adjusting the gas and oxygen for each zone. The control panel contains two single loop controllers, two digital gas flow meters, two digital oxygen flow meters, six digital temperature meters, status lights for the main fuel train, E-stop, alarm horn, and alarm silence push button.



Control Panel

Oxy-Fuel Control System

- Both the gas and oxygen skids have essentially the same safety system. A strainer is utilized prior to a pressure regulator. A high/low pressure switch is tied to the double block automatic shut-off valves. A differential pressure switch is used to determine flow through the system. This is a safeguard against injecting raw natural gas or oxygen into the furnace. If flow is lost on either natural gas or oxygen, the skid shuts down that zone. Each zone is then automatically controlled for gas and oxygen flows via a signal from the mass flow meter to a control loop back to an automatic valve.


Melter Refractory

- Refractory selection has been developed for this pilot melter based on the heat flow analyses for each construction type. These are used to insure that none of the materials is placed in temperatures beyond their capability and to determine the total heat loss of the entire system.


Side of Melter in Operation

- The use of refractory selected by evaluating the abrasive qualities of the molten sediment. Glass products vary according to the chemical makeup of the feedstock. After the June run, an inspection of the inside of the forehearth verified that the refractory material at the glass line was seeing significant wear. The melter was relined with a higher grade refractory in place of the mullite originally installed in the melter for the August run.

- The melter was designed and built under a contract with Frazier-Simplex of Washington, Pennsylvania.

- The melter uses a "shallow" glass line. Glass melters typically have deeper pools of glass inside the melter, taking advantage of the low opacity of the glass being produced. Molten sediments are quite opaque, thus reducing energy transfer by radiation.

Inspection of Glass Line

Warm Up Burner

- Startup of the melter is performed gradually over 36-48 hours. A separate, dedicated warmup burner is used to raise the temperature of the melter to approximately 1,400 degrees F. After this temperature, the main burners are used to reach final temperature target of 2,900 degrees F.

EXTRACTION PROBE DESIGN AND CONSTRUCTION

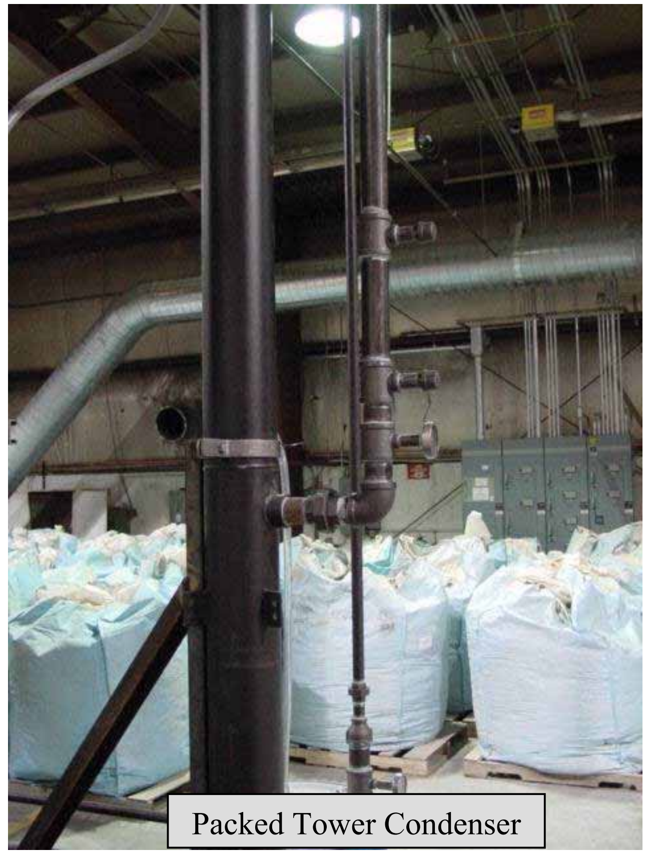
- The purpose of the extraction probe is to cool the hot gas from the melter exhaust at a controlled rate. The rate of cooling would be equivalent to the heat recovery systems installed on a full scale melter system. The extraction probe was designed by Minergy. The section of the probe which is inserted into the melter is contained in a water-cooled jacket, and is hung from a rail that allows it to be inserted into the stack for testing, then removed when testing is not taking place.

Extraction Probe

- A cleanout port is placed on the back end of the probe, and a brush and rod are used to manually clean out particulate buildup within the probe.

Probe Clean-out

- Piping connects the extraction probe to a contact packed tower condenser. An induced draft fan pulls the exhaust gases through the tower condenser, and then through a carbon barrel, before discharging the air stream out of doors.


Packed Tower Condenser


Carbon Filter

- A heat exchanger loop cools the water in the packed tower condenser. Sampling ports are located before the condenser and after the carbon filter, to allow connection of air testing equipment.

SEDIMENT PREPARATION

The Fox River sediment supplied to Minergy for the pilot melter project contained about 50% moisture by weight. The melter was designed to process sediment containing approximately 10% moisture. Minergy contracted Hazen Research, Inc. (4601 Indiana St., Golden, CO) to determine the material handling characteristics of the sediments and to evaluate moisture removal by indirect drying. It was determined that Fox River sediment, when mixed with drier materials to reduce its moisture content to 37%, would handle easily when undergoing drying activities to bring its moisture content down to 10%.

Hazen dried a batch of Fox River sediment to approximately 10% moisture. The EPA sampled and tested the various medias involved to determine the fate of contaminants during the drying process. Results of that testing will be submitted by the contractors responsible for the testing.

Flux is often a necessary addition to the feed material in glass melters as an oxidizer and for scum control. Minergy contracted Corning Glass Works to mix various concentrations of fluxing compounds with sample sediment from the Fox River, melting the mixed material and observing its melt characteristics.

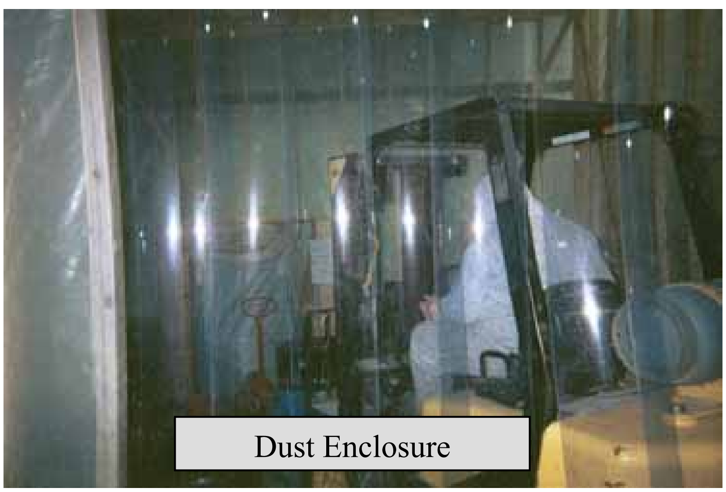
The pilot project used a flux mix ratio of 5% sodium sulfate by weight.

The pre-processing of the river sediment in the Winneconne facility occurred in a series of steps:

Drying

Barrel Drying Oven

Minergy purchased a 75-kW electrically-heated drying unit, and dried the river sediment at the Winneconne facility. Twelve barrels of sediment were dried together in a batch. Each batch underwent low-temperature drying, with sediment temperature below 210 degrees F, for 36 hours. A 10-inch diameter wire cage was placed inside each barrel prior to drying to increase heat transfer and evaporation rates. Thirty batches of river sediment were processed, filling 60 supersacks.



Dust Enclosure

A 20-foot by 20-foot dust enclosure was built for controlling dust during sediment processing activities. With the exception of the drying activities in the oven, all processing activities took place within the dust enclosure.

The dried river sediment was removed from the oven, and the barrels were dumped into supersacks. Each supersack contained six barrels of river sediment, so each oven batch was transferred into two supersacks. Each supersack weighed approximately 1,100 pounds.

Supersack of Dried Sediment

Each supersack was numbered, to identify when its material was dried, and the lugger from which its material originated.

RIVER SEDIMENT
MINERAL ANALYSIS by
XRF for MAJOR ELEMENTS

Batch Number	Na20	MgO	Al203	Si02	P205	K20	CaO	Ti02	Fe203
1	0.43	9.95	9.60	36.3	0.37	1.70	35.9	0.71	2.85
2	0.43	9.71	9.12	34.5	0.36	1.65	34.1	0.66	2.53
3	0.39	10.1	9.42	34.3	0.38	1.56	37.5	0.70	2.75
4	0.43	11.3	9.33	35.3	0.36	1.49	36.3	0.69	2.75
5	0.38	10.1	9.35	35.2	0.36	1.58	35.7	0.69	2.64
6	0.49	10.2	10.1	38.4	0.36	1.82	31.2	0.69	2.71
7	0.50	10.3	10.1	38.4	0.38	1.76	31.1	0.72	2.82
8	0.39	9.20	9.40	34.6	0.35	1.74	36.5	0.68	2.58
9	0.50	8.96	10.1	38.7	0.38	1.83	32.3	0.71	2.71
10	0.45	9.70	9.90	36.5	0.37	1.69	35.1	0.71	2.70
11	0.47	9.56	9.81	37.5	0.37	1.74	34.7	0.71	2.69
12	0.44	8.78	9.62	35.1	0.37	1.59	36.4	0.70	2.66
13	0.51	9.62	9.94	38.0	0.36	1.83	33.2	0.70	2.73
14	0.43	9.64	9.67	35.5	0.37	1.70	35.6	0.70	2.98
15	0.44	11.6	9.77	37.8	0.35	1.68	33.7	0.71	2.69
16	0.44	10.3	9.93	36.6	0.37	1.73	35.0	0.73	2.79
17	0.47	10.2	9.85	37.2	0.36	1.82	35.4	0.72	2.74
18	0.44	9.87	9.59	35.8	0.35	1.82	37.9	0.71	2.63
19	0.49	10.4	9.60	37.7	0.36	1.73	34.8	0.69	2.63
20	0.57	9.77	9.87	38.1	0.33	1.81	32.7	0.69	2.95
21	0.43	9.72	9.48	36.8	0.35	1.77	34.0	0.67	2.54
22	0.45	9.20	9.96	38.0	0.37	1.86	35.7	0.72	4.29
23	0.46	10.8	9.88	39.0	0.37	1.84	33.3	0.70	4.26
24	0.40	8.99	9.75	37.2	0.36	1.81	36.4	0.69	4.52
25	0.40	8.53	9.48	35.8	0.35	1.72	39.4	0.68	4.19
26	0.40	8.83	9.64	36.0	0.36	1.63	38.8	0.71	4.24
27	0.41	9.10	10.2	36.6	0.38	1.73	37.1	0.74	4.41
28	0.37	10.6	9.54	34.3	0.37	1.57	38.9	0.69	4.21
29	0.39	8.86	9.62	36.8	0.36	1.74	37.8	0.69	4.31
30	0.39	9.91	9.87	34.8	0.37	1.62	38.1	0.72	4.74

Mineral Analysis of Dried Sediment

Delumping

The supersacks containing dried river sediment were unloaded through a delumper, reducing particle size of the sediment.

Sampling

Samples were retrieved from one foot below the surface of the material in each supersack to analyze for moisture and mineral content. Select material was also analyzed for loss on ignition. The results of the mineral analysis are included at left.

Metal Separation

The delumped sediment was passed through a grate containing 13 bar magnets, placed in four rows offset to each other. Significant amounts of magnetic material were separated.

Mixing/Bagging

The dried river sediment was mixed with a sodium sulfate flux. The ratio of sediment to flux varied from supersack to supersack due to variations in moisture content among the various runs. The appropriate amount of flux was added to each drum of dried river sediment, and the barrels were rolled on the floor to mix the contents. The mixture was then poured into approximately 50-pound bags, which were marked with their weight and the supersack number from which they originated. The bags were loaded on a pallet. Each pallet contained all the bags of sediment/flux mix produced from a single supersack, so that during melting operations, material processing could take place based on moisture content and lugger of origination..

Batch Bags of Dried Sediment

All sediment processing activities were carried out within the dust enclosure. Workers wore Tyvek suits with full-face air filtration. A negative air machine was connected to the dust enclosure to remove particulates from the air.

JUNE 2001 TRIAL

The June 2001 trial took place from June 16 – 23, 2001, on a 24 hours per day schedule. Featured during this test run was a series of four public and media relations events Monday and Tuesday, June 18-19.

Media Relations Activities

Shakedown of the melter system was delayed for several days due to a severe storm which occurred June 11, the originally planned startup date. The storm resulted in an extended power outage to the facility (approximately 4 days). Public relations had been planned for Monday June 18 and Tuesday June 19, featuring a number of high-profile visitors who had arranged their schedules to visit the demonstration. To maintain the schedule, shakedown of various systems was eliminated. Instead, the unit was put into continuous production at the earliest possible time.

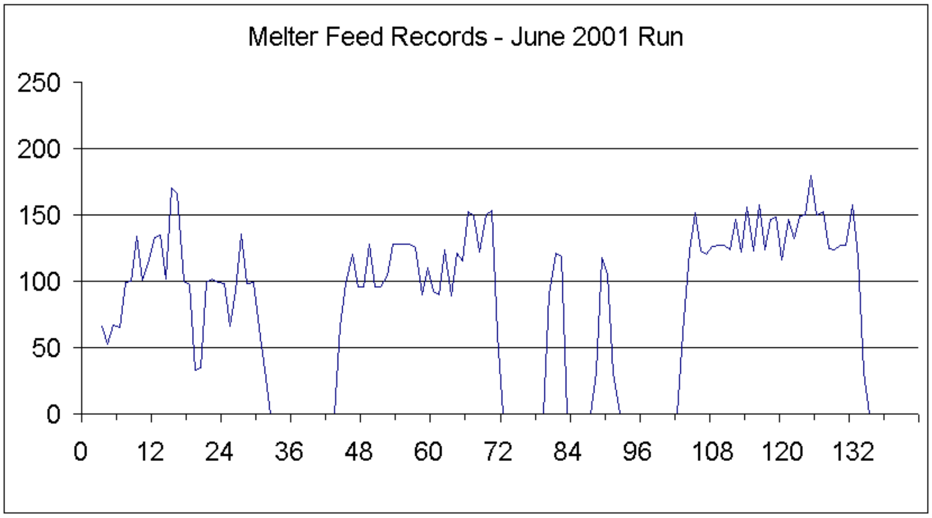
Public Relations Tours

The melter was brought up to temperature slowly from Saturday, June 16 to Monday, June 18. The first river sediment was fed into the melter at 3:00 a.m. on June 18.

The run was interrupted on a number of occasions, due to clogging of the batch charger, clogging of the tap, and a power outage. The operation of the extraction probe was shut down on a number of occasions due to plugging of the filters in the air testing equipment. Many of the equipment problems can be attributed to having performed what otherwise would have been shakedown during the operational timeframe.

The run was concluded when representatives from Frazier-Simplex suspected degradation of the forehearth section of the melter. The total run time was insufficient to provide adequate sampling required in the EPA's plan

Approximately 10,700 net pounds of river sediment had been processed at the time. The oxy-fuel train was shut down, and the melter was allowed to cool down over a period of a week.



Inspections And Modifications

An inspection of the inside of the forehearth verified that the originally specified refractory material at the glass line was subject to accelerated wear. The melter was relined with a higher grade refractory in place of the mullite originally installed in the melter.

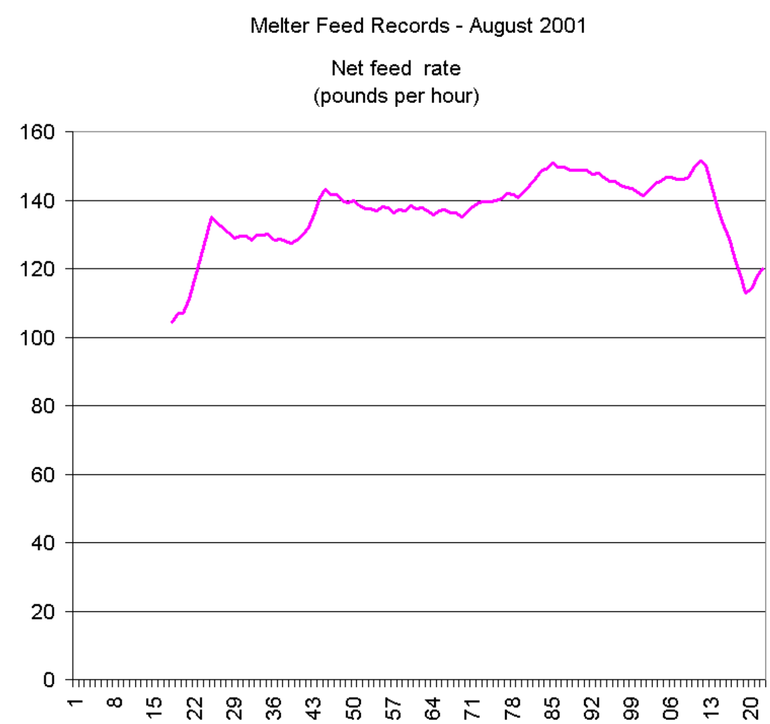
AUGUST 2001 TRIAL

The August 2001 trial took place from August 11 – 18, 2001. Melting operations took place 24 hours per day. This trial went smoothly, attributable to the fact that significant systems had been shaken down and tested during the June run. In the interim timeframe, optimizations were made that allowed for a successful run in August.

After the melter was rebuilt in July, the August run took place smoothly and uneventfully. Steady state conditions were achieved fairly quickly, and with the exception of two periods of downtime involving the extraction probe/air emissions assembly, steady state was maintained until completion of the testing.

The melter was brought up to temperature slowly from Saturday, August 11 to Monday, August 13. The first river sediment was fed into the melter at 6:00 a.m. on August 13. Air testing started at midnight on Tuesday, August 14, and was carried out routinely until 7:00 a.m., Saturday, August 18.

Approximately 16,500 net pounds of river sediment were processed during the August trial.



OBSERVATIONS

The pilot project determined that river sediment melts easily at high temperature into a hard, angular aggregate. The melter worked well with this type of feedstock, and the end product appeared consistent and marketable. When river sediment was being fed into the melter, temperatures within the melter were maintained between 2600 and 2900 degrees F.


Molten Glass Tapping


Clearing the Tap

The pilot melter was designed for a relatively low flow rate of glass through the melter tap. As expected, the tap refractory did not reach temperatures sufficient to provide for unattended tapping of glass. To keep the tap open, a secondary external gas fired burner was used, and operators used metal bars to loosen prematurely cooled aggregate.

Extraction Probe

The extraction probe needed routine maintenance. When hot exhaust gases were drawn into the water-cooled extraction probe, condensation took place, which tended to capture particulates moving through in the exhaust gas. When flow through the probe decreased significantly due to particulate build-up, the cleanout port was opened and the probe was cleaned.

Sediment Feed

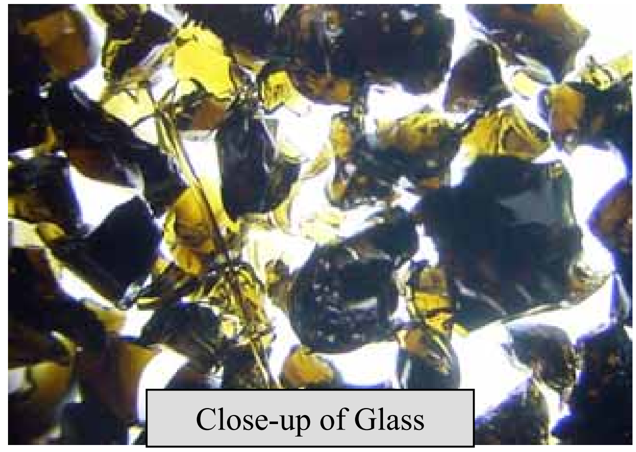
The moisture content of the river sediment affected feed rates. Moisture contents ranged from 5% to 20%. River sediment with higher moistures tended to bridge in the charger, and to cake around the auger. A technician permanently observed the feeding process, to make sure the charger was always feeding material to the melter.

Air Quality Control

The downstream end of the extraction probe assembly, involving the condenser, carbon barrel, and associated piping and pumps, suffered plugging due to accumulation of particulate and sulfates, primarily attributable to the use of sodium sulfate as a flux. The condenser cooling water was blown down periodically to alleviate the potential for low pH.

SUMMARY

The Phase III demonstration clearly showed that dried sediment will successfully create a quality glass aggregate material using a glass furnace. The properties of the glass aggregate product were quite positive. The aggregate was very consistent, producing a hard, dark, granular material.



Close-up of Glass

Leach tests performed on the aggregate by the WDNR showed no detect for PCBs or any trace metals. This confirms the original goal of the project: the glass aggregate product is a quality material, PCB-free, with excellent leaching characteristics.

DNR Parameter Description	Result value
ARSENIC TCLP	ND
BARIUM TCLP	0
CADMIUM TCLP	ND
CHROMIUM TCLP ICP	ND
LEAD TCLP	ND
MERCURY TCLP	ND
PCB SUM OF CONGENEI	ND
SELENIUM TCLP	ND
SILVER TCLP	<0
ZINC TCLP	ND

Shortly after the completion of the demonstration, the DNR participated in the construction and dedication of a picnic shelter along the Fox River. At the DNR's request, glass aggregate from the demonstration run was used in the foundation of the picnic shelter. A plaque was installed to inform the public about the success of the demonstration project.

Product marketing specialists are analyzing the glass qualities to determine the marketability of the material. Based on Minergy's experience in marketing similar glass products, and given the high quality of this material, we are confident that all of the glass aggregate produced in a commercial-sized facility would be successfully marketed. The indicated list shows the preliminary assessment of the suitability for using glass aggregate from river sediment in various markets.

Minergy Corporation
Glass Aggregate Marketing
Chemical and Physical Property Guidelines

Roofing Shingle Granules	Target	Glass Aggregate	Accept?	Method
Loose Bulk Density	> 80 lbs/cf	90 lbs/cu ft	Yes	Weight/volume
Fe2O3 (for opacity)	> 5%	7%	Yes	ASTM 4326
Hardness	>5.5	6.2	Yes	Moh's mineral scale
Crystalline Silica content	<1%	no detect	Yes	X-Ray Diffraction
Leachability	TCLP test	passes	Yes	TCLP method 1311
Particle size	>80% between #12-#30	passes (crushed)	Yes	ASTM C136

Industrial Abrasives	Target	Glass Aggregate	Accept?	Method
Loose Bulk Density	> 80 lbs/cf	90 lbs/cu ft	Yes	Weight/volume
CaO	< 50%	17%	Yes	ASTM 4326
Al2O3	< 40%	10%	Yes	ASTM 4326
Fe2O3	< 20%	7%	Yes	ASTM 4326
Hardness	>5.5	6.2	Yes	Moh's mineral scale
Crystalline Silica content	<1%	no detect	Yes	X-Ray Diffraction
Leachability	TCLP test	passes	Yes	TCLP method 1311
Particle Size	>80% between #16-#50	passes (crushed)	Yes	ASTM C136
Embedment	<20%	7%-15%	Yes	KTA Tater Test

Ceramic Floor Tile	Target	Glass Aggregate	Accept?	Method
Loose Bulk Density	> 80 lbs/cf	90 lbs/cu ft	Yes	Weight/volume
Crystalline Silica content	<1%	no detect	Yes	X-Ray Diffraction
CaO	< 50%	17%	Yes	ASTM 4326
Glass Melting Point	> 2000 $^{\circ}$F	2200 $^{\circ}$F	Yes	ASTM 965
Particle Size	>80% between #16-#50	passes (crushed)	Yes	ASTM C136
Tile Strength	> 15 Mpa	22 Mpa	Yes	MOR/3-E (*)

Cement Pozzolan	Target	Glass Aggregate	Accept?	Method
Particle Size	480 m2/kg	passes (crushed)	Yes	ASTM C618
Iron-Alumo-Silicate	> 50%	52% - 60%	Yes	ASTM 114
L.O.I.	<6%	no detect	Yes	ASTM 114 ch.16
Cement Strength (3 day)	2535 psi	2850 psi	Yes	ASTM C311
Cement Strength (7 day)	3470 psi	3680 psi	Yes	ASTM C311
Cement Strength (28 day)	3953 psi	5300 psi	Yes	ASTM C311

Construction Fill
Acceptable gradation and compaction.