Appendix G

Glass Aggregate Feasibility Study

G Glass Aggregate Feasibility Study

Executive Summary

During the comment period of the 2001 draft of the Lower Fox River RI/FS, WDNR completed a project to evaluate the feasibility of a vitrification technology, based on standard glass furnace technology, to treat contaminated sediment. Following the release of the 1999 Draft RI/FS, Minergy Corporation prepared a proposal for a multi-phased study to determine the treatment and cost effectiveness of this technology to destroy organic contaminants (primarily PCBs) and immobilize inorganic contaminants (primarily heavy metals) in river sediments. Minergy Corporation proposed a four-phased feasibility study for the testing of a glass furnace technology and proposed to cost share the study. With funding assistance from EPA's GLNPO, WDNR accepted Minergy Corporation's proposal to conduct the Glass Furnace Technology Feasibility Study. Also, recognizing the extreme scrutiny PCBs have been under and the need for a thorough independent evaluation of contaminant fate, WDNR requested assistance from the EPA SITE Program. The SITE Program agreed to independently undertake the evaluation of cost and treatment effectiveness for this project.

Initially the four proposed phases of the study were:

- **Phase I:** Mineralogy and sediment characterization;
- **Phase II:** Crucible melt and preliminary design engineering;
- **Phase III:** Pilot-scale sediment melt of dewatered dredge material; and
- **Phase IV:** Full-scale facility construction.

WDNR and Minergy Corporation agreed to conduct Phases I through III. Minergy Corporation approached the feasibility of this technology from the perspective of designing a system that would produce a high quality, reusable glass aggregate product. They recognized that the conditions necessary to produce a quality glass aggregate product would also be ideal for destruction of organic contaminants, such as PCBs. Many trace metals found in sediment are permanently immobilized in the melting and quenching process, producing a final aggregate product that is very inert.

Phase I testing characterized the mineral composition of river sediments to estimate the glass quality, durability, and melting point. Sixteen archived river sediment samples, representing the entire 39 river miles, that were collected during previous investigations were analyzed for mineral composition and loss on ignition (LOI). The mineral composition of the river sediments was very consistent throughout the river and is very favorable for producing a quality glass product. The low results generated in the LOI tests confirm that a melting technology is more appropriate for river sediments than an incineration technology. With these positive results in hand, the project moved into Phase II.

During Phase II, crucible melts of 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). Fluxes are added to the batch material to optimize the mineral composition, which in turn minimizes the amount of energy necessary to melt the material. The four different "recipes" were tested and all successfully melted the sediment into glass. The addition of limestone, as a fluxing agent, to the sediment provided the best results (Minergy Corporation, 1999). Phase II results included 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 not using an existing glass furnace for Phase III testing. Results of Phase II testing indicated that:

- The cost to retrofit an existing facility to the specification needed to melt sediment would be as much as building a pilot melter to these same specifications;

- Most existing facilities are too large to accommodate a limited duration test and would not provide the ability to adequately sample the various waste streams to determine destruction efficiency; and

- Use of oxy-fuel burners would be most energy efficient.

Together, the results of Phase I and II indicated that the glass furnace construction and operating costs could allow the processing and melting of the river sediments to be considered an economically viable option. Therefore, Minergy Corporation and WDNR initiated Phase III, the construction and operation of a pilot-scale glass furnace, specially designed to generate the operational data, treatment effectiveness data, and cost information needed for scale-up to a full-scale facility (Phase IV). The glass furnace technology process consists of two basic steps: a sediment drying step followed by the vitrification (melting) step. Due to the potential to release contaminants during both steps and the limited scale of this phase, treatment of approximately 60 tons of dredged and dewatered sediment, it was necessary to evaluate these two steps independently. Both processes were independently evaluated by the EPA SITE Program. The evaluation of the drying step was completed using a bench-scale

Holoflite® dryer at Hazen Research, Inc.'s Golden, Colorado facility. Results from the dryer will not be discussed here because the waste streams from this process can and will be incorporated directly into the design of the melter thus effectively treating these waste streams. However, the dryer evaluation did provide some insights into the material handling characteristics of the sediment including (Hazen, 2001):

- Fox River sediments can be physically modified to provide flowable feed to a dryer;
- The amount of moisture in the sediments can be reduced to less than 10 percent;
- Heat transfer coefficients and thermal efficiencies;
- Dewatered sediment exhibited stickiness or agglomerating characteristics at less than 65 percent solids; and
- Dewatered sediment at greater than 65 percent solids did not exhibit sticky or agglomerating characteristics.

The pilot-scale glass furnace is simply a refractory-lined rectangular melter (refer to Figure 6-11). The refractory is brick or concrete that 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. Natural gas is fired in the furnace, raising the internal temperatures to between 2600 and 3000 °F. Exhaust treatment is simplified and energy efficiency improved by the melter's use of purified oxygen (oxy-fuel) rather than ambient air as the oxygen source. At these temperatures, the sediment melts and flows out of the furnace as molten glass. Due to low gas volumes produced by the oxy-fuel melter and the large volume of gas space above the molten line, gases remain resident in the melter for a significant period of time (greater than 2 seconds). These conditions are more extreme than the conditions demonstrated to destruct PCBs. Other vitrification technologies have demonstrated greater than 99.9999 percent destruction of PCBs (cite NY/NJ WRDA work in WEDA). In addition, any trace metals in the molten glass will be stabilized when it is quenched and the glass matrix is formed.

The two primary objectives of Phase III testing were (EPA SITE, 2000):

- **P1** To determine the treatment efficiency (TE) of PCBs in dredged and dewatered river sediment when processed in the Minergy Corporation glass furnace technology (GFT); and

- **P2** To determine whether the GFT glass aggregate product meets the criteria for beneficial reuse under relevant federal and state regulations.

In addition, there were three secondary objectives:

- **S1** Determine the unit cost of operating the GFT on dewatered dredged river sediment;

- **S2** Quantify the organic and inorganic contaminant losses resulting from the existing or alternative drying process used for the dredged and dewatered river sediment; and

- **S3** Characterize organic and inorganic constituents in all GFT process input and output streams. Of principal concern is the formation of dioxin and furan during the vitrification step.

Phase III was completed in August 2001. During the pilot, approximately 50 tons of dredged and dewatered river sediment was processed through the melter. This phase clearly showed that the glass furnace technology created a quality glass aggregate material from river sediments. The properties of the glass aggregate were quite positive and were very consistent, producing a hard, dark, granular material (Minergy Corporation, 2001).

The EPA SITE Program has released the validated results of the chemical testing conducted during Phase III. As described in the Quality Assurance Project Plan (QAPP) (EPA SITE, 2001), all input and waste streams were sampled during the pilot. Testing was performed for a wide range of chemicals including congener PCBs ($n = 78$), dioxins/furans, SVOCs, VOCs, and heavy metals. In addition, the glass aggregate was subjected to both American Society for Testing and Materials (ASTM) water leaching procedures and SPLP procedures.

The sediment charged into the melter during the pilot testing averaged 28.1 milligrams of PCB per kilogram (mg-PCB/kg). Exhaust gas emissions were sampled on the pilot melter before and after the air quality control equipment. The average PCB concentration of the exhaust after the air quality control equipment was 36.6 nanograms per dry standard cubic meter (ng/DSCM) meter). In comparison, the average PCB concentration of the exhaust before the air quality control equipment was only slightly higher at 45.9 ng/DSCM. Thus, on an hourly average post-air quality control stack basis, this equates to PCB destruction of greater than 99.99993 percent during the pilot.

The formation of dioxins and furans during the thermal treatment of PCB-contaminated sediment was identified as a concern during the development of the sampling plan and were sampled. The sediment on average contained 23.5 and 65.6 ng/kg 2,3,7,8-TCDD and 2,3,7,8-TCDF, respectively. No 2,3,7,8-TCDD was detected in either the pre- or post-air quality control equipment samples. 2,3,7,8-TCDF was detected at an average of 0.0018 ng/DSCM post-air quality control equipment. Therefore, on an hourly average basis during the pilot, 8,815.5 ng of 2,3,7,8-TCDD and 2,3,7,8-TCDF were loaded into the melter while less than 0.1 ng of only 2,3,7,8-TCDF was emitted. This not only represents a greater than 99.998 percent reduction in 2,3,7,8-TCDD/TCDF, but more importantly that these compounds are not created to any extent during this treatment process.

Using the results from the pilot melter, the emissions from a 250 glass tons per day full-scale facility were calculated. The facility would meet all current state and federal air emissions regulations and is not expected to trigger the major source thresholds (Minergy Corporation, 2002).

The glass aggregate also demonstrated acceptable characteristics for beneficial reuse. As identified in the project QAPP (EPA SITE, 2001), the glass aggregate did not exceed any of the criteria specified. In fact, the ASTM water leach test and SPLP test did not detect any 2,3,7,8-TCDD/TCDF, not a single PCB congener, any SVOCs, nor any of the eight heavy metals.

In response to EPA SITE's need to also determine the cost of the technology, Minergy Corporation performed a *Unit Cost Study for Commercial-Scale Sediment Melter Facility* (Minergy Corporation, 2002). This report used standard build-up estimating approaches in developing the cost estimates. This approach used the information generated in Phases I, II, and III and on that basis requested relevant cost, performance, and sizing data from equipment suppliers. With this data, the general plant layout (Figure FVRS-GA-101 from Unit Cost Report presented in Appendix G), mass and energy balance, and equipment arrangements were made. From this, estimates were done for construction and operations and, through financial modeling, a unit-cost forecast. The base case estimates were made using a plant size of 250 glass tons per day. Sensitivity analysis was also conducted for various sized melter plants with and without integrated storage. Table 4 from the Unit Cost Report presented in Appendix G summarizes the unit costs developed during this study.

The glass furnace technology incorporates and optimizes several factors to achieve greater cost and treatment effectiveness than other thermal processes, including rotary kilns. These factors include:

1. **Oxy-Fuel.** The use of pure oxygen (rather than atmospheric air) and natural gas has the added benefits of:

    a. Substantially reducing pollutant emissions thereby reducing capital and annual operating expenses associated with air quality control equipment; and

    b. Higher heat transfer and thermal efficiencies which together increase throughput in an existing facility or reduce the size of new facilities (see Baukal, 1998 for a review of oxy-fuel combustion).

2. **The Use of Highly Insulating Refractory.** A glass furnace is able to utilize several layers of refractory brick, thus increasing the insulating value and keeping the oxy-fuel heat inside the furnace. In comparison, other thermal processes like rotary devices for vitrification can have thinner refractory linings and thus may have up to three times the amount of heat loss.

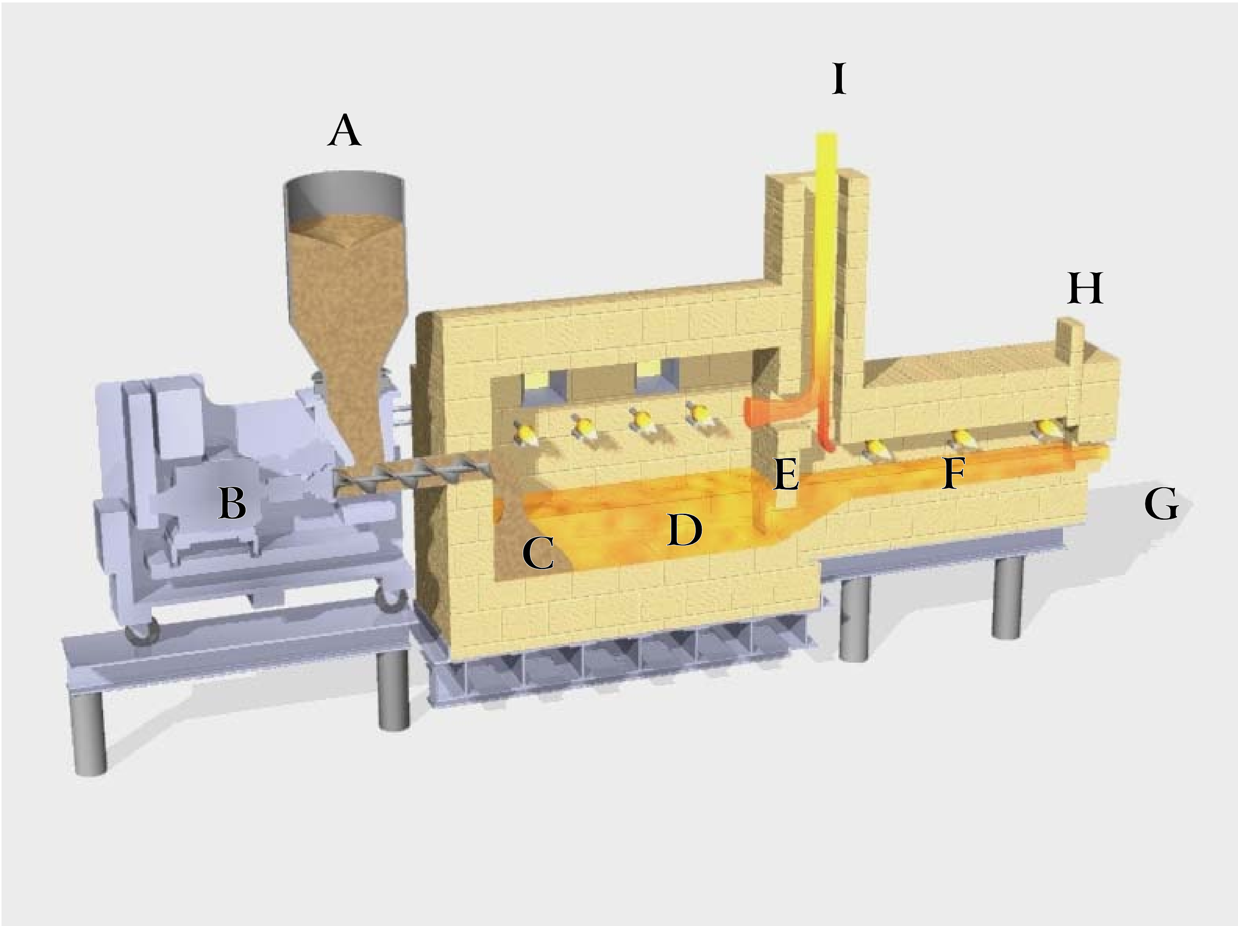
3. **Use of a Dryer to Remove Water from the Sediment.** Many other technologies process wetter material and, therefore, a substantial portion of the energy consumption is used in super-heating water to the same temperature as the sediment.

Thermal recovery from the glass furnace can provide a significant portion (85 percent) of the energy to pre-dry sediment before introduction into the glass furnace.

Table 1 X-Ray Fluorescence Elemental Analysis and Stepped Loss on Ignition Analysis

Date Collected		**Nov. 11**	**Nov. 11**								**6/3/1998**	**6/3/1998**	**6/5/1998**	**6/5/1998**	**6/5/1998**	**6/5/1998**
Lab #		**A**	**B**	**5297**	**5300**	**5290**	**5299**	**5298**	**5289**	**5291**	**5295**	**5296**	**5292**	**5293**	**5294**	**5301**
Al_2O_3	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
SiO_2	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
Fe_2O_3	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
TiO_2	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
Na_2O	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
P_2O_5	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
K_2O	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
LOI-550				10.9	8.9	12.6	8.0	10.8	6.8	7.4	8.9	2.8	7.9	5.2	9.9	11.6
LOI-750				15.1	13.6	17.2	12.5	16.1	10.7	9.2	13.5	3.1	11.3	8.4	15.1	18.0
Sample Designation	Dep N	Marina	Marina	95001-01	95015-01	95049-01	95055-06	95075-04	95068-01	95100-01	SDC-EE22-1-G-45-55	SDC-EE22-1-G-45-55	SDC-X-4-G-45-55	SDC-W-5-G-45-55	SDC-E-4-G-45-55	SDC-C-1-G-45-55

Figure 1 Glass Furnace Process Description



Sediment (A) is fed into 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 (not shown). 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 top of the furnace to the air quality control equipment (not shown).

Figure 2 Processing Facility Conceptual Layout

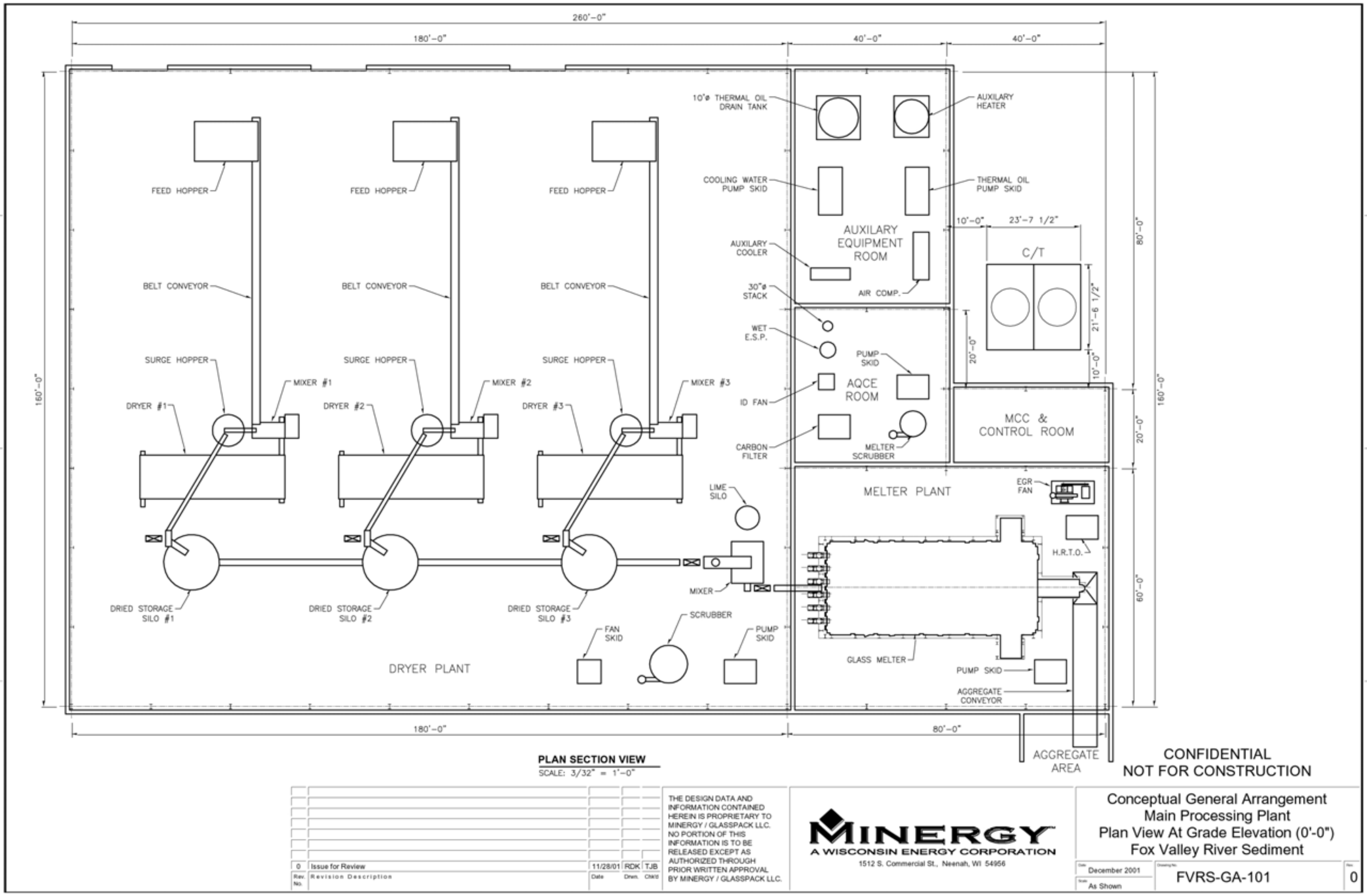


Table 2 Summary of Sensitivity Options: Sediment Melting Plant

	1×100 Integrated No Storage	1×100 Integrated Storage	1×250 Integrated No Storage	1×250 Integrated Storage	1×250 Standalone No Storage	1×250 Standalone Storage	2×250 Standalone No Storage	2×250 Standalone Storage	2×375 Standalone No Storage	2×375 Standalone Storage
Daily Capacity (tons)	240	240	613	613	613	613	1,226	1,226	1,840	1,840
Days/year Operation	240	350	240	350	240	350	240	350	240	350
Project Life (years)	15	15	15	15	15	15	15	15	15	15
Sediment Processed (million tons)	0.86	1.26	2.21	3.22	2.21	3.22	4.41	6.44	6.62	9.66
Capital ($ million)	25.50	26.25	36.99	38.79	34.97	36.77	63.19	66.79	87.39	92.79
Annual O&M ($ million)	2.30	2.76	4.73	6.13	5.44	6.84	9.29	12.17	12.57	16.74
NPV before Glass Sales ($ million)	49.35	54.86	86.04	102.40	91.44	107.81	159.58	193.16	217.88	266.50
Unit Cost (assuming $2 glass) (dollars per ton of wet cake)	**$56.54**	**$42.96**	**$38.41**	**$31.24**	**$40.86**	**$32.92**	**$35.58**	**$29.43**	**$32.32**	**$27.01**
Unit Cost (assuming $25 glass) (dollars per wet ton of cake)	**$49.91**	**$36.33**	**$31.78**	**$24.61**	**$34.23**	**$26.29**	**$28.95**	**$22.80**	**$25.68**	**$20.38**

FINAL REPORT
SEDIMENT MELTER
DEMONSTRATION PROJECT

TABLE OF CONTENTS

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

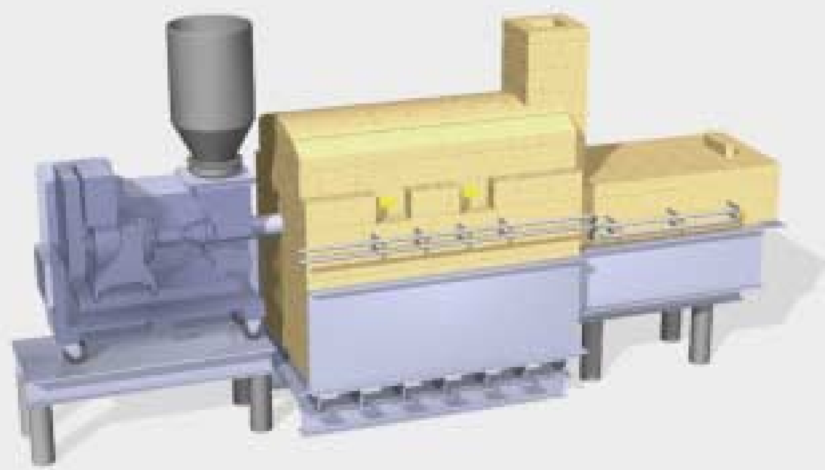
The U.S. EPA Superfund Innovative Technology Evaluation (SITE) program was used to perform an independent evaluation of the fate of PCB and other contaminants for Phase III. The dryer segment of the analysis was performed at the Hazen Research, Inc. facility in Golden, Colorado in January 2001. At that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


Sediment Melter

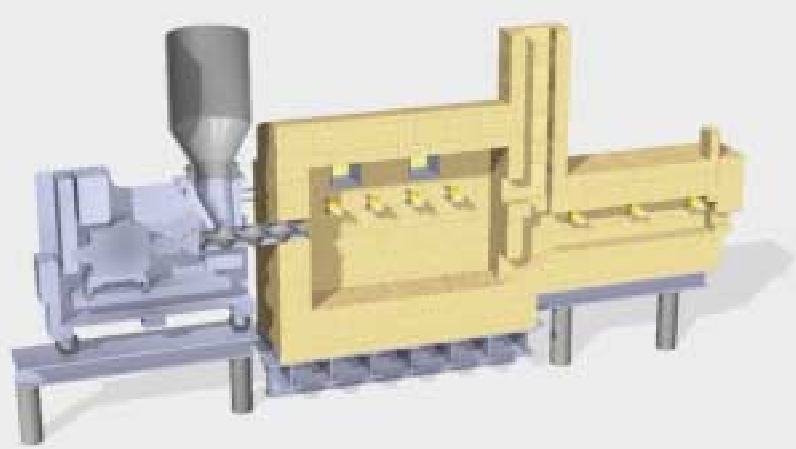
The melter evaluation was performed at Minergy's GlassPack Test Center in Winneconne, Wisconsin. A demonstration-scale melter was constructed, with operation of the melter from May to August, 2001. The pilot program was designed to confirm that the technology can destroy PCB contamination, stabilize 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

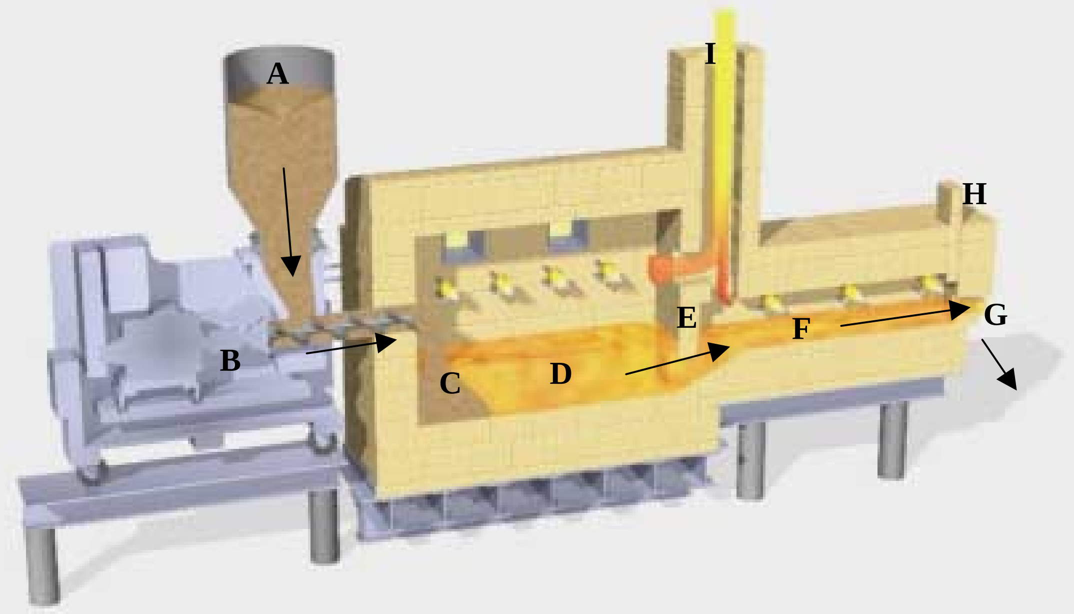


Fig 3. Internal view of melter (sediment feeding and melting)

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

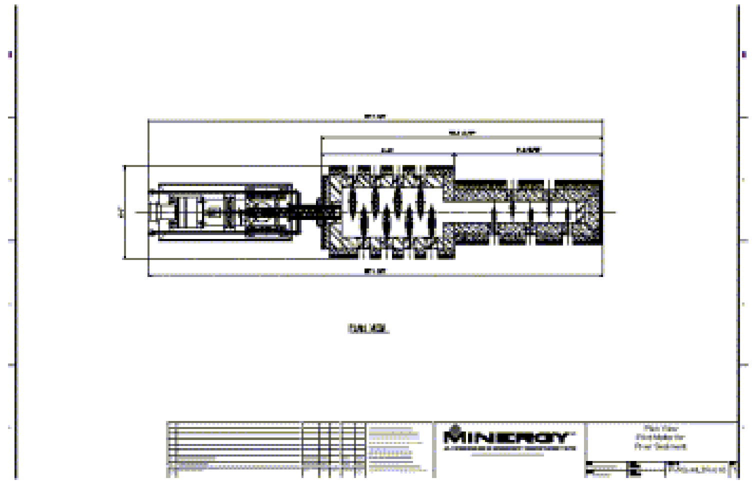
Date Collected	1/5/99	Nov. 11	Nov. 11	9/28/95	9/30/95	10/3/95	10/4/95	10/5/95	10/7/95	10/12/95	6/3/98	6/3/98	6/5/98	6/5/98	6/5/98	6/5/98
Lab #		A	B	5297	5300	5290	5299	5288	5289	5291	5295	5296	5292	5293	5294	5301
Al_2O_3	10.70	5.03	4.55	9.03	14.10	10.20	14.70	14.20	11.80	10.60	13.80	13.20	11.80	12.80	13.70	11.20
SiO_2	63.70	76.90	80.50	80.90	63.10	58.90	59.20	62.10	58.30	65.80	62.30	58.40	55.50	62.10	61.10	55.50
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
Fe_2O_3	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
TiO_2	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
Na_2O	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
P_2O_5	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	0.28	<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
K_2O	3.48	2.04	2.16	2.87	2.95	2.92	3.25	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

Top View of Melter

- 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.

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 Screw Charger

- 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.

Air Filtration on Sediment Hopper

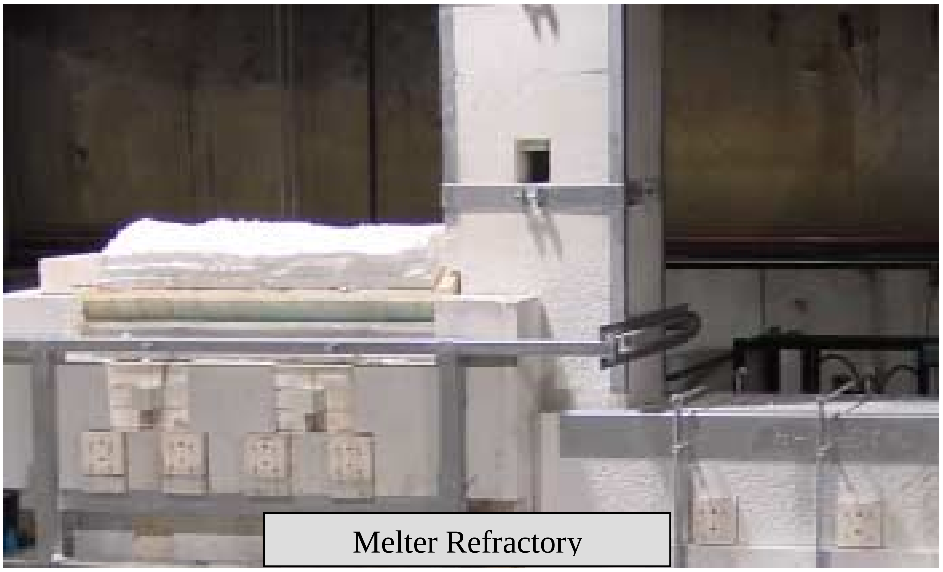
- Negative pressure is placed on the feed hopper during charging operations to control dust.
- The melter design capacity is 2 tons per day or 170 pounds of river sediment per hour. The sediment bags weighed approximately 50 gross pounds, so the feed rate was expected to be between four and five bags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

Extraction Probe

- 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.

Probe Clean-out

- 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.

- 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	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	Fe_2O_3
1	0.43	9.95	9.60	36.3	0.37	1.76	35.9	0.71	2.85
2	0.43	9.71	9.12	34.6	0.38	1.65	34.1	0.66	2.53
3	0.39	10.1	9.42	34.3	0.38	1.56	37.6	0.70	2.76
4	0.43	11.3	9.33	35.3	0.38	1.46	36.3	0.69	2.75
5	0.38	10.1	9.35	35.2	0.38	1.58	35.7	0.69	2.64
6	0.49	10.2	10.1	38.4	0.38	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	9.30	9.40	34.6	0.35	1.74	36.5	0.68	2.58
9	0.50	8.98	10.1	38.7	0.38	1.83	32.3	0.71	2.71
10	0.45	8.70	9.60	36.5	0.37	1.86	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	1.72	35.6	0.70	2.66
15	0.44	11.6	9.77	37.6	0.35	1.88	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	9.80	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	2.66
21	0.43	8.72	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	35.6	0.35	1.72	39.4	0.68	4.19
26	0.40	8.83	9.64	36.0	0.36	1.63	36.8	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	1.67	36.9	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	9.57	34.8	0.37	1.62	36.1	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.

<u>Metal Separation</u>

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.

<u>Mixing/Bagging</u>

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.

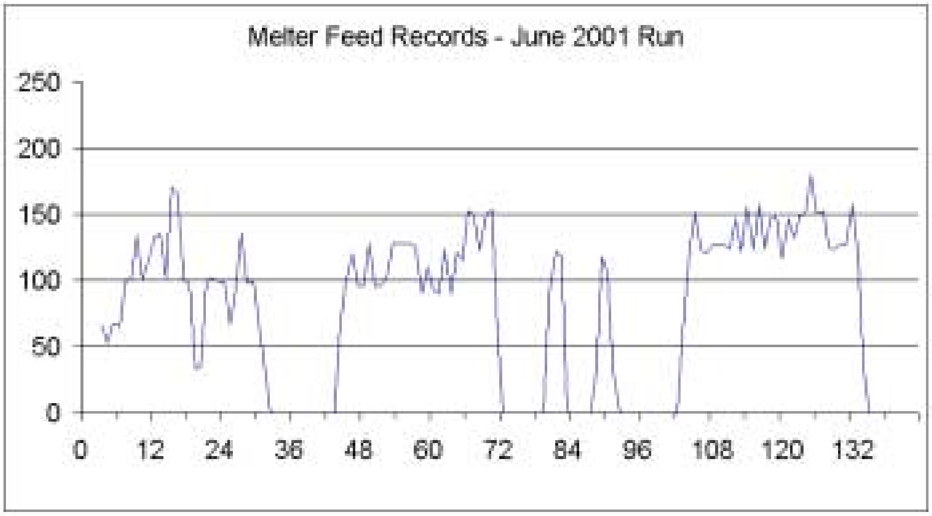
Public Relations Tours

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

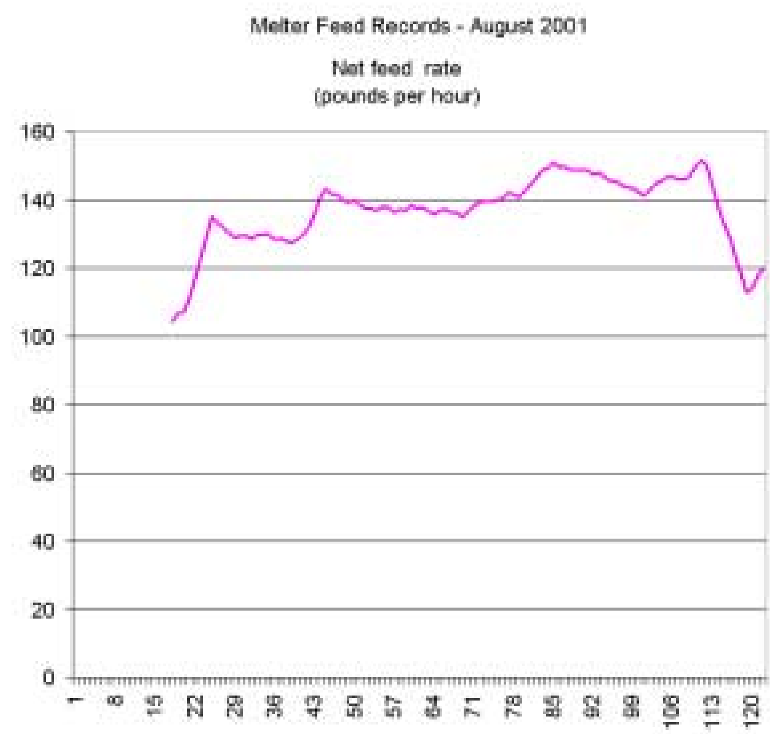
An inspection of the inside of the forehearth verified that the originally specified refractory material at the glass line was subject to accelerated wear. The melter was relined with a higher grade refractory in place of the mullite originally installed in the melter.

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.

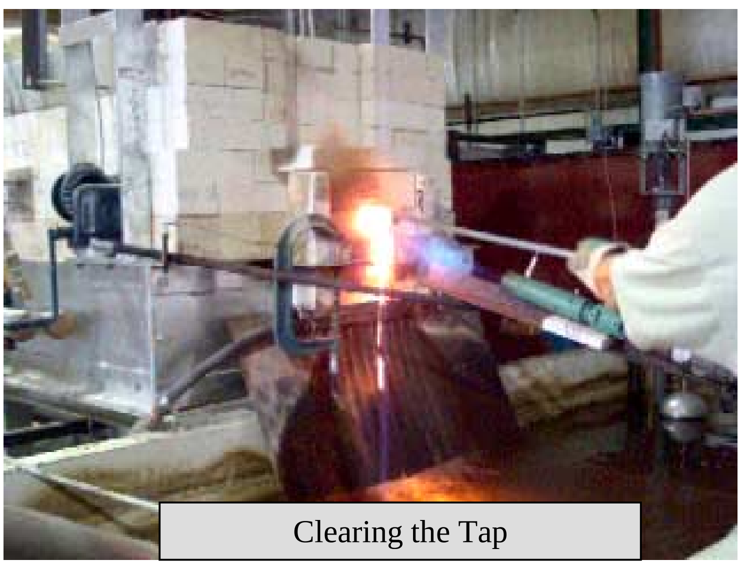


Approximately 16,500 net pounds of river sediment were processed during the August trial.

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.

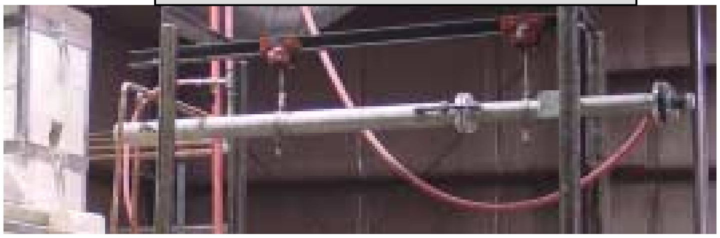
Molten Glass Tapping



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

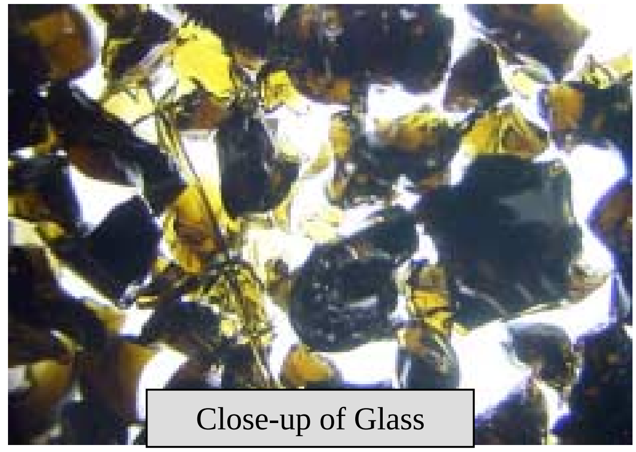
The moisture content of the river sediment affected feed rates. Moisture contents ranged from 5% to 20%. River sediment with higher moistures tended to bridge in the charger, and to cake around the auger. A technician permanently observed the feeding process, to make sure the charger was always feeding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

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.

Air Quality Control

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 °F	2200 °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.

UNIT COST STUDY
FOR COMMERCIAL-SCALE
SEDIMENT MELTER FACILITY

FOR

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

SUPPLEMENT TO

GLASS AGGREGATE FEASIBILITY STUDY

JANUARY 19, 2002

UNIT COST STUDY
FOR COMMERCIAL-SCALE
SEDIMENT MELTER FACILITY

TABLE OF CONTENTS

INTRODUCTION

Minergy Corporation respectfully submits this report to the Wisconsin Department of Natural Resources (the “Department”) containing the results of the Unit Cost Study For Commercial-Scale Sediment Melter Facility. This work was necessary to fulfill the requirements of the U.S. EPA’s Quality Assurance Project Plan (“QAPP”) as part of their reporting of the pilot sediment melter. The activities leading to this report are in conjunction with the Glass Aggregate Feasibility Study under the agreement between Minergy and the Department dated September 21, 2000, (State of Wisconsin purchase order number NMJ00001936), as amended under State of Wisconsin purchase order number NMB0000488.

Minergy used a standard build-up estimating approach in performing the Cost Study. This approach used the information derived from Phases 1, 2, and 3 of the Glass Aggregate Feasibility Study, and on that basis, Minergy requested relevant cost, performance, and sizing data from equipment suppliers. With this data, the general plant flowsheet, mass & energy balance, and equipment arrangements were made. From this, estimates were done for construction and operations, and through financial modeling, a unit-cost forecast.

The base case estimates are made using a plant size of 250 glass tons per day. This size is consistent with that used elsewhere in the Glass Aggregate Feasibility Study. A sensitivity analysis is included for various sized melter projects.

This report is the result of a Cost Study and not an offer to construct a facility. The engineering performed within the scope of this study does not represent final detail. Further detail engineering and design would improve the accuracy of the Cost Study results. Notwithstanding the Department’s or any other party’s desire to proceed with detail engineering or the development of a commercial scale facility, Minergy nonetheless reserves the right to make final determination on Minergy’s participation.

PROCESS DESCRIPTION

This section describes the process and equipment used in the base project with a capacity of 250 glass tons per day. The facility is designed to melt 600 tons per day of partially dewatered river sediment that has been dredged from the Fox River.

The sediment enters the plant, is mixed with previously dried sediment to make it easier to handle, and is then dried to approximately 10% moisture. (See Drawing FVRS-PF-101 – Process Flow Diagram, Sediment Drying and Preparation, and Drawing FVRS-GA-101 – Conceptual General Arrangement, Main Processing Plant.) After the sediment is mixed with a fluxing material, it is fed into a large melter, capable of maintaining temperatures in the 2900 ^{o}F range. The sediment melts into a molten material, which drains from the melter, is quenched in a water bath, and turns into a glass aggregate. The melter is designed to produce 250 tons per day of aggregate, which will be sold for building products.

The entire process is optimized to conserve energy, reduce heat losses, and minimize labor requirements.

Sediment Preparation (pre-drying)

Sediment is dredged and hydraulically transported to the dewatering site, and mechanically dewatered by others at the site. The material is moved by front-end loader into the short-term storage/mixing area in the dryer plant. Three wet sediment mixers are installed in the dryer plant. (See Drawing FVRS-PF-101 – Process Flow Diagram, Sediment Drying and Preparation.) Each mixer has a rating of 11.3 tons per hour. Sediment, which has already been dried (total moisture content is approximately 10%), is added to the inlet of the mixer. The purpose for the mixing is to improve material handling and behavior in the dryers, by eliminating the self-agglomeration or“sticky phase” of the material. The moisture content of the sediment after mixing is approximately 39%.

Sediment Drying

After the sediment has been prepared by mixing, it is transported by enclosed conveyors to the sediment dryer (See Drawing PC1100309 – Holo-Flite Dryer.) The heat source for the dryers will be high temperature thermal oil. The sediment moisture content is reduced in the dryers from 39% to 10%. Water vapor from the drying of the sediment is exhausted to a vapor collection system, as described in *Dryer exhaust gas treatment system*, below.

Dry Sediment Storage and Dry Sediment Feed Mixer

Each drying line will have a 110-ton live bottom storage hopper, for a total of 330 tons of dry sediment storage. The dry sediment storage hopper discharges sediment to a small 9-ton surge hopper at the wet sediment mixers or to a dry sediment mixer. A 200-ton lime silo provides a supply of ground limestone to the feed mixer to work as a fluxing agent for control of the melting temperature. The dry sediment mixer will have a capacity of 9.2 tons. A conveyor will transport the material discharged form the dry sediment mixer to the melter inlet surge hopper.

Melter Feeding and Operation

A total of six chargers supply the melter with dry and fluxed river sediment. (See Drawing Q8596-006 – Melter Plan View.) The melter heats the sediment to 2500 ^{o}F to 2900 ^{o}F. The molten material exits the main melter section and enters the forehearth. The forehearth then drains the hot glass into a water-filled quench tank. The glass furnace is heated with oxy-fuel fired burners. The burners are supplied by the fuel rails. Oxygen is provided by an on-site oxygen generation plant. Hot exhaust gas generated by the melter is exhausted into a hot gas heat recovery system and air quality control system (AQCS) prior to the exhaust stack.

Melter Quench Tank

The quench tank is water-filled, and receives the hot glass flow from the melter. The direct contact of the hot gas with the water will cause the material to solidify and fracture into the glass aggregate product. A set of screws will withdraw, dewater and transport the material to an adjacent storage pile. The quench tank will be in a closed cooling water loop. The quench tank temperature will be maintained by constant circulation of water through a set of heat exchangers.

Melter Off-Gas Treatment

The exhaust gas from the melter exits at 2700 to 2850 ^{o}F into the exhaust flue. (See Drawing FVRS-PF-102 – Process Flow Diagram, Melter Exhaust Heat Recovery and AQCE.) The exhaust flue also receives cool exhaust gas from an exhaust gas recirculation fan, which blends the cooler and hotter gases together within the flue. The cooled flue gas enters a heat recovery/thermal oil (HRTO) unit. The HRTO heats thermal oil, which is used to supply energy to the sediment drying process. The flue gas exiting the HRTO is split into two parts. The first part is used as flue gas recirculation, and is routed back through a flue gas recirculation fan (FGR) into the blending section of the melter exhaust gas flue. The second part of the flue gas flow enters a high-energy venturi and packed tower section. The venturi section removes particulate from the exhaust, and the packed tower section removes SO_2. The water in the packed tower is in a closed recirculation loop. The packed tower operates in the condensing mode, requiring some blowdown water from the loop. Sodium hydroxide is added to the process to control pH and provide for optimum SO_2 removal.

After the exhaust gas exits the packed tower, the flue gas enters a wet electrostatic precipitator (wet ESP). This device provides additional control and is especially effective for fine particulate. The exhaust flow from the wet ESP proceeds to a carbon filter bed. The carbon filter bed provides for absorption of mercury, and can also absorb PCBs and other chlorinated organic compounds. After the exhaust gas exits the carbon absorber, the gas is exhausted through a 95-foot tall and 30-inch diameter stack.

Thermal Oil Energy Supply and Distribution System

The main purpose of the thermal oil system is to provide thermal energy to the sediment dryers for the drying process. (See Drawing FVRS-PF-104 – Process Flow Diagram, Thermal Oil Supply System.) The system consists of the following components:

(1) A thermal oil auxiliary heater, which uses natural gas to heat thermal oil. The amount of natural gas fired in the unit is a function of the dryer plant energy demand.

(2) The HRTO unit, which recovers energy from the melter hot exhaust gas.

(3) An auxiliary heat sink (AHS), which dissipates heat in the event that one or all of the sediment dryers are not operational, while the HRTO continues to recover heat from an operational melter. The AHS unit is a standard shell and tube heat exchanger. Heat will be dissipated to the circulation water system.

(4) Circulation pumps and control valves, which provide the necessary energy to force the circulation of the thermal oil at the required process conditions.

(5) A thermal oil expansion tank.

(6) A thermal oil drain tank. Both items (5) and (6) are standard features for thermal oil systems, and are necessary for proper operation and maintenance of the system.

Dryer Exhaust Gas Treatment System

The process of sediment drying forces water that is contained in the wet sediment feed to vaporize, while the sediment is in contact with the heated components of the sediment dryer. To assist in efficient removal of the water vapor, a controlled volume of sweep air is admitted into the dryer housing. (See Drawing FVRS-PF-103 – Process Flow Diagram, Dryer Off Gas Treatment.) At the opposite end of the dryer housing, the combined water vapor and sweep air are exhausted from the dryer unit. The exhaust gas passes through a mechanical collector. The mechanical collector removes a significant fraction of the sediment dust that is entrained in the water vapor/sweep air mixture that is exhausted from the dryer. The dust is collected and the material is recombined with the dry sediment in any one of the dry sediment storage silos.

To provide for a "zero emissions" design, the water vapor/sweep air mixture is introduced into a venturi scrubber and packed tower arrangement. This device is similar in function to the venturi collector and packed tower used on the melter exhaust gas treatment system. The venturi collector removes an additional fraction of entrained sediment dust from the dryer exhaust stream. The water vapor is then condensed and removed by the packed tower section of the unit. A steady stream of water is circulated from a closed cooling water loop to the top of the packed tower. The condensing process increases the water volume in the cooling loop, requiring some blowdown of water to a wastewater treatment facility.

The exhaust gas that exits the packed tower section is circulated by an exhaust fan. The entire dryer and exhaust system operates under a negative pressure condition to prevent fugitive dust emissions from the dryer casings. Since some inward air leakage is expected, a small vent stream will be split off from the exhaust fan. The exhaust stream will be directed to one of the burners on the melter. This will provide destruction of any organics in the dryer exhaust. The balance of the exhaust fan discharge is directed back to the sediment dryers as the sweep air source.

Circulating Cooling Water System

A number of systems will require a steady stream of cooling water to remove heat. All of the systems use non-contact heat exchangers to prevent contamination of the cooling water system. The cooling system is a closed system. Heat is dissipated through a mechanical draft cooling tower. Make-up water is required to recover some evaporative losses from the system. Blowdown water will need to be drained from the cooling tower to limit total dissolved solids (TDS) concentrations in the water.

Circulating water is pumped to the users by motor-driven centrifugal pumps. The major users of circulation water are:

(1) Indirect heat exchanger for exhaust gas packed tower cooling system.
(2) Indirect heat exchanger for dryer exhaust gas packed tower cooling system.
(3) Aggregate quench tank indirect cooling heat exchanger.
(4) Cooling water for the thermal oil auxiliary heat dissipation unit.
(5) Charger cooling water.
(6) Cooling water required for the oxygen generation system.

ASU Oxygen Supply

Oxygen will be generated on-site. The approximate oxygen volume needed will require the generation of 171 tons of oxygen per day. The oxygen will be generated with a technology called gaseous oxygen generation, or GOX. This technology generates oxygen at a purity of 99.5%. The oxygen is generated in the gas phase (non-cryogenic). The plant will be completely designed and constructed from the foundations up by a third party. No detailed process description is included in this scope document. The sediment drying and melting facility will need to interconnect utilities and infrastructure to the oxygen plant to minimize infrastructure development costs. The main requirement will be the supply of 4160V power from the dryer and melting facility electric substation to the ASU.

Dust Control System

All of the sediment conveyors, storage hoppers and silos will have a closed design. To prevent fugitive emissions from the conveyor systems, they will be ventilated continuously. The exhaust will be directed to a high efficiency fabric filter. All collected dust will be directed back to one of the dry sediment storage silos.

Plant Wastewater Summary

There are three sources of process wastewater for the operation. The condensate from the dryer exhaust results in a waste stream of 48 GPM. This waste stream has a wastewater loading of 1000 to 3000 ppm of total suspended solids (TSS). The suspended solids will consist of fines that are carried out of the dryers. There is a potential that PCBs are attached to the sediment particles, requiring this flow stream to be treated by the same wastewater treatment facility processing the dredged sediment.

The packed tower on the exhaust of the melter generates 15 GPM of constant blowdown. This flow stream will have high concentrations of both TSS and chemical oxygen demand (COD), and will need to be sent for additional wastewater treatment. The discharge volume and concentration levels will not require any pretreatment prior to discharge to the publicly owned treatment works (POTW).

The cooling tower generates a maximum blowdown flow of 37 GPM. This flow can be permitted as a non-contact cooling water source. If the proper permits are obtained, it is possible to either discharge the water into the stormwater sewer system or into the final effluent of the wastewater treatment facility for the dredge water.

SUMMARY OF ASSUMPTIONS

Several assumptions were made in preparing the Cost Study estimates contained in this report. These assumptions were made based on our understanding of the scope of the project at the time of the award of the Department's Purchase Order. Others were made based on equipment design features provided by suppliers and the data which was then available. Final engineering and design would address variances from the assumptions.

1. The following assumptions were made relative to incoming sediment:
    a. Previously de-watered to 50% solids
    b. Previous removal of all debris, including metal and other material greater than ¼-inch in size
    c. Received in a non-frozen state, even during winter operations
    d. Gross calorific value (GCV) of approximately 1300 Btu per pound
    e. Loss on ignition of approximately 29%
    f. Fluxing requirement of 15% lime
    g. Self-agglomeration does not occur at 39% moisture or lower
2. The following assumptions were made relative to facility permitting:
    a. No hazardous waste incinerator regulations apply
    b. Oxyfuel is best available control technology (BACT) for NO_x control
    c. Wet scrubber at 95% control is BACT for SO2
3. The following assumptions were made relative to the facility design:
    a. Facility is staffed for 24 hours per day, year-round
    b. Site soils are capable of loading to 2500 pounds per square foot
    c. No provisions have been incorporated for soil testing or boring
    d. No compactor is assumed necessary for feeding to the melter
    e. The dryers require 10 Btu per square foot per degree F
    f. Facility design will be for an industrial area
4. The following assumptions were made relative to the cost of supplies:
    a. The gas price was assumed to be $3.25 per million Btu
    b. The electricity price was assumed to be 4½ cents per kilowatt hour

c. The lime flux cost was assumed to be $25.00 per ton
d. The oxygen cost is assumed to be 6 cents per hundred cubic feet from a 3rd party

5. No provisions were included for the following items:
   a. Salvage/removal at the end of the plant's economic life
   b. Dredging, dewatering, and delivery of cake solids
   c. Hedges or other financial instruments on commodity prices
   d. Site development costs other than those explicitly listed
   e. Financing costs during and after plant construction and working capital requirements

COST SUMMARIES

Capital Costs

The cost to build the melter facility is estimated to be approximately $36,800,000. (See Table 1 – Projected Capital Costs.) The primary equipment costs include the melter ($7,500,000, installation included), the material handling system ($3,000,000), and the dryers ($2,600,000). The main building is estimated at $2,600,000 and the sediment storage building is $1,800,000. Mechanical and electrical contracting is expected to be $10,000,000.

Operating Costs

The cost to operate the melter facility is estimated to be approximately $6,800,000 annually. (See Table 2 – Projected Operating Costs.) The primary cost drivers for the facility would be labor, supplies, and fuel.

Unit Cost Analysis

Over the 15-year projected life of the facility, approximately 3.15 million tons of contaminated river sediment would be processed. The present worth of the project, assuming construction and operating costs listed above, a State of Wisconsin interest rate of 5% (used as the discount rate), and glass sales of $2 to $25 per ton, is between $84,600,000 and $106,000,000. This results in a present worth unit cost between $26.29 and $32.92 per ton. (See Table 3 – Estimated Present Worth Cost for 250 Glass Ton per Day Sediment Melting Plant.)

SENSITIVITY ANALYSIS

Overview

A series of sensitivity analyses have been performed on the base project. These analyses estimate the capital, O&M, and unit cost of melter projects of varying sizes. These costs were derived using a combination of build-up estimates, generally accepted scale factors, and operational experience. The base case project was used as a reference.

Each major capital line item was analyzed to determine the new expected values, factoring in the impacts of the larger or smaller sized plants. For example, the slope of the cost curve of a melter is rather flat because a large portion of the cost of a melter is fixed. Sediment dryer plants, in comparison, scale fairly well due to the use of multiple dryer lines for each facility (increasing or decreasing the capacity of the plant is done by using more or fewer dryer lines).

The O&M line items were also analyzed individually to determine the new expected values. These items fall into two categories: fixed and variable O&M. Variable O&M items include natural gas, oxygen, electricity, and lime flux, the consumption of which varies in proportion to the amount of processing. Fixed O&M included staffing, G&A, and maintenance, although these items were individually estimated for each plant size.

Project Sizes

The project sizes were varied as indicated:

A. 1 x 250: This is the base case project described in this report. This facility has one sediment melter rated at 250 glass tons per day and three dryers rated at 200 wet ton per day (each), along with the associated balance of plant.
B. 2 x 250: This facility has two sediment melters each rated at 250 glass tons per day and six dryers rated at 200 wet ton per day (each), along with the associated balance of plant.
C. 2 x 375: This facility has two sediment melters each rated at 375 glass tons per day and ten dryers rated at 180 wet ton per day (each), along with the associated balance of plant.

D. 1 x 100: This facility has one sediment melter each rated at 100 glass tons per day and one dryer rated at 250 wet ton per day, along with the associated balance of plant.

Sediment Storage

The sensitivity analysis included provisions for each project to operate at 240 or 350 days per year. Limiting operations to 240 days per year would coincide with the 8-month dredging season, and avoid the capital expenditure of a building to store sediment and minimize potential permitting problems with storing such material and reduce. To operate 350 days per year, a storage would be used into which one-third of the de-watered sediments would be placed during the dredging season. During the non-dredging season, the accumulated inventory would be used as feedstock to the melter plant. For each 250 glass ton per day increment of capacity, sufficient storage could be accomplished using a 60,000 square foot building. The estimated cost of such a building would be $1.8 million per 250 glass ton/day unit.

Stand-alone Facility Design

The melter projects can be designed to be stand-alone facilities or integrated into the operation of an adjacent industrial facility with which it can share resources. Integration tends to be more applicable to the smaller projects (1x100 and 1x250). It was assumed that the 1x100 project would not be feasible without integration with an existing industrial facility. The 1x250 project was studied both as a stand-alone and as integrated. The 2x250 and 2x375 plants have sufficient volume to allow full independent staffing, and therefore were studied as stand-alone.

A provision was also included to account for special foundation requirements associated with integrated projects. This is because many area industrial plants are located along shorelines with poor soil load bearing capacities.

CONCLUSION

At the beginning of the Glass Aggregate Feasibility Study, Minergy had performed some preliminary analyses that indicated a unit cost in the range of $40 - $60 per ton. The results from the Cost Study confirm those initial results.

Table 1
Projected Capital Costs for 250 Glass Ton per Day Sediment Melting Plant

Item	Cost
Melter (delivered and installed)	$ 7,511,976
Dryer (total for 3, equipment only)	$ 2,588,505
Material handling system	$ 3,019,923
Dryer off gas system equipment	$ 394,515
Thermal oil system equipment	$ 995,579
AQCE system equipment	$ 468,931
BOP equipment	$ 845,081
Utilities equipment	$ 488,383
Mechanical contractor	$ 7,886,711
Electrical contractor	$ 2,113,548
Start-up costs	$ 763,277
Main building	$ 2,634,966
Engineering	$ 5,274,684
Sediment Storage Building	$ 1,800,000
TOTAL:	$ 36,768,000

Table 2
Projected Operating Costs for 250 Glass Ton per Day Sediment Melting Plant

Item	Annual Cost
Gas	$1,315,860
Electricity	$1,086,750
Labor	$2,125,000
Supplies	$1,612,310
Lime Flux	$447,125
G&A	$257,000
TOTAL:	$6,844,045

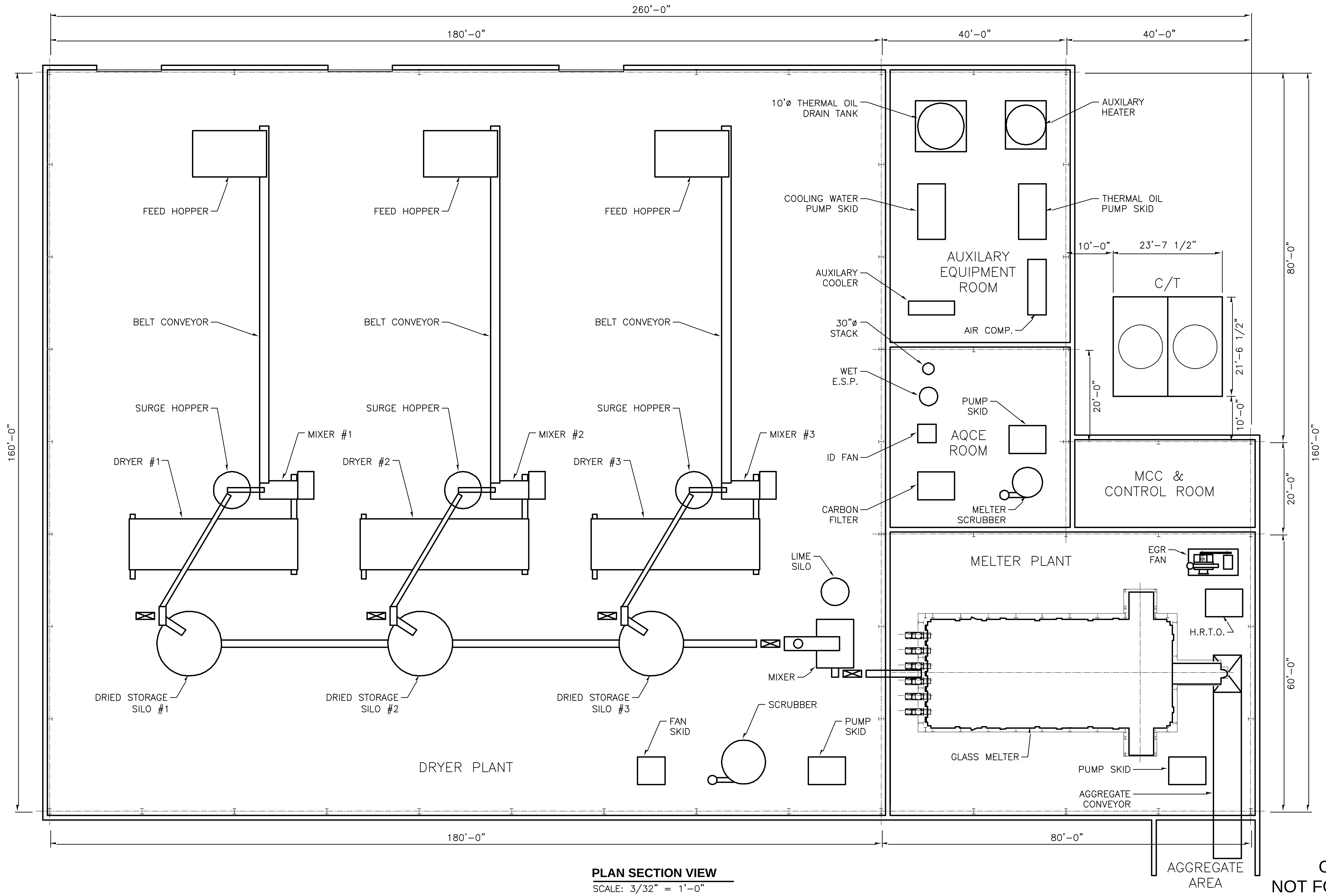
Table 3
Estimated Present Worth Cost for 250 Glass Ton per Day Sediment Melting Plant

Assumptions:		
Project life =	15	years
Interest rate =	5.0%	
Days per Year =	350	
Sediment processing rate =	613	tons daily
Total sediment processed =	3,218,250	tons over project life
Construction costs =	$36,768,000	
Operating costs =	$6,844,000	annually
Income from glass sales =	$2 - $25	per ton of glass sold
Glass production rate =	255	tons daily

Estimated Costs:	**Initial Costs**	**Net Annual Costs**
Construction costs	$36,768,000	
Operating costs with no glass sales		$6,844,000
Operating costs minus glass income at $2/ton		$6,665,208
Operating costs minus glass income at $25/ton		$4,609,104
Total Present Worth Cost of Project:		
No glass sales	$107,806,380	
With glass sales at $2/ton	$105,950,583	
With glass sales at $25/ton	$84,608,925	
Unit Costs (Per Ton of Sediment Processed):		
No glass sales	$33.50	
With glass sales at $2/ton	$32.92	
With glass sales at $25/ton	$26.29	

Table 4
Summary of Sensitivity Options
Sediment Melting Plant

	1x100 Integrated No Storage	1x100 Integrated Storage	1x250 Integrated No Storage	1x250 Integrated Storage	1x250 Standalone No Storage	1x250 Standalone Storage	2x250 Standalone No Storage	2x250 Standalone Storage	2x375 Standalone No Storage	2x375 Standalone Storage
Daily capacity (tons)	240	240	613	613	613	613	1,226	1,226	1,840	1,840
Days/yr Operation	240	350	240	350	240	350	240	350	240	350
Project Life (years)	15	15	15	15	15	15	15	15	15	15
Sediment Processed (million tons)	0.86	1.26	2.21	3.22	2.21	3.22	4.41	6.44	6.62	9.66
Capital ($million)	25.50	26.25	36.99	38.79	34.97	36.77	63.19	66.79	87.39	92.79
Annual O&M ($million)	2.30	2.76	4.73	6.13	5.44	6.84	9.29	12.17	12.57	16.74
NPV before Glass Sales ($million)	49.35	54.86	86.04	102.40	91.44	107.81	159.58	193.16	217.88	266.50
Unit Cost (assuming $2 Glass) (dollars per ton of wet cake)	**$ 56.54**	**$ 42.96**	**$ 38.41**	**$ 31.24**	**$ 40.86**	**$ 32.92**	**$ 35.58**	**$ 29.43**	**$ 32.32**	**$ 27.01**
Unit Cost (assuming $25 Glass) (dollars per wet ton of cake)	**$ 49.91**	**$ 36.33**	**$ 31.78**	**$ 24.61**	**$ 34.23**	**$ 26.29**	**$ 28.95**	**$ 22.80**	**$ 25.68**	**$ 20.38**



PLAN SECTION VIEW

SCALE: 3/32" = 1'-0"

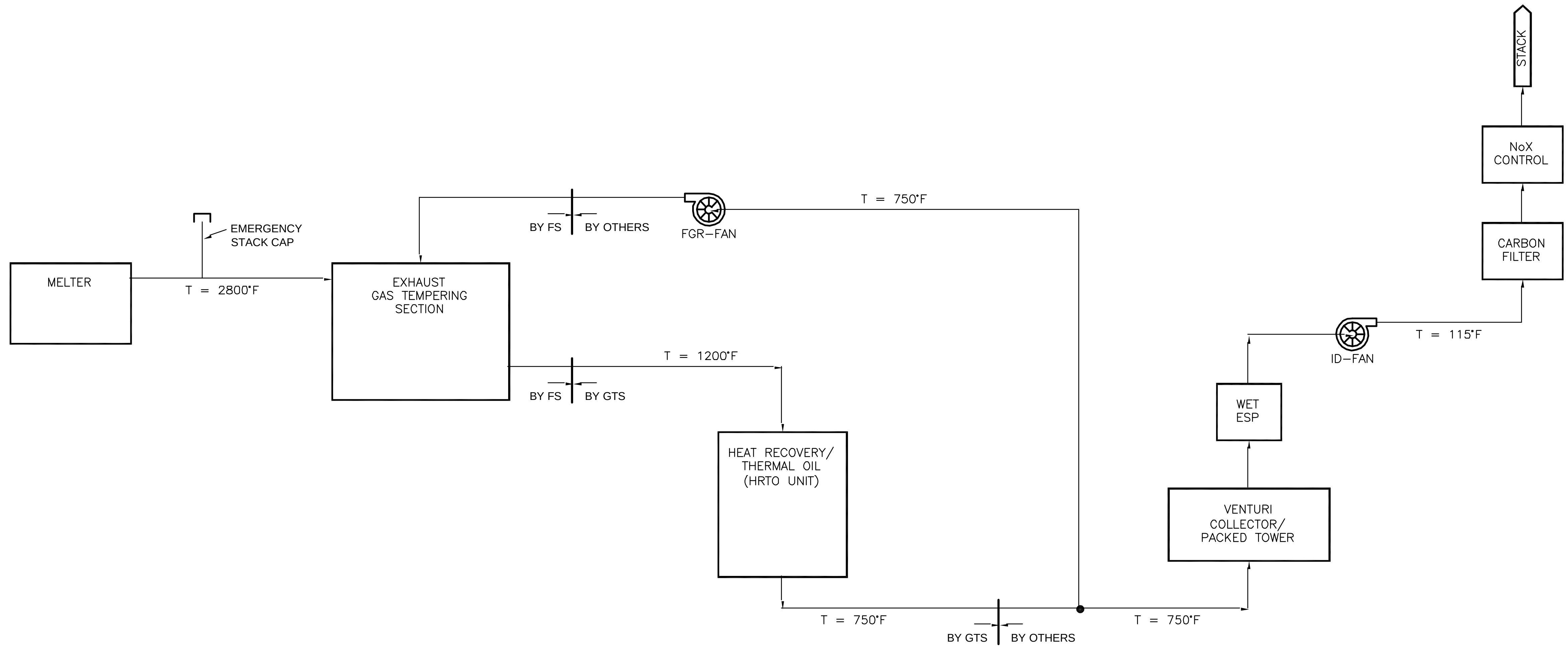
CONFIDENTIAL
NOT FOR CONSTRUCTION

Rev. No.	Revision Description	Date	Drwn.	Chk'd
0	Issue for Review	11/28/01	RDK	TJB

MINERGY™
A WISCONSIN ENERGY CORPORATION
1512 S. Commercial St., Neenah, WI 54956

Conceptual General Arrangement
Main Processing Plant
Plan View At Grade Elevation (0'-0")
Fox Valley River Sediment

Date: December 2001
Drawing No.: FVRS-GA-101
Rev.: 0
Scale: As Shown



Rev. No.	Revision Description	Date	Drwn.	Chk'd

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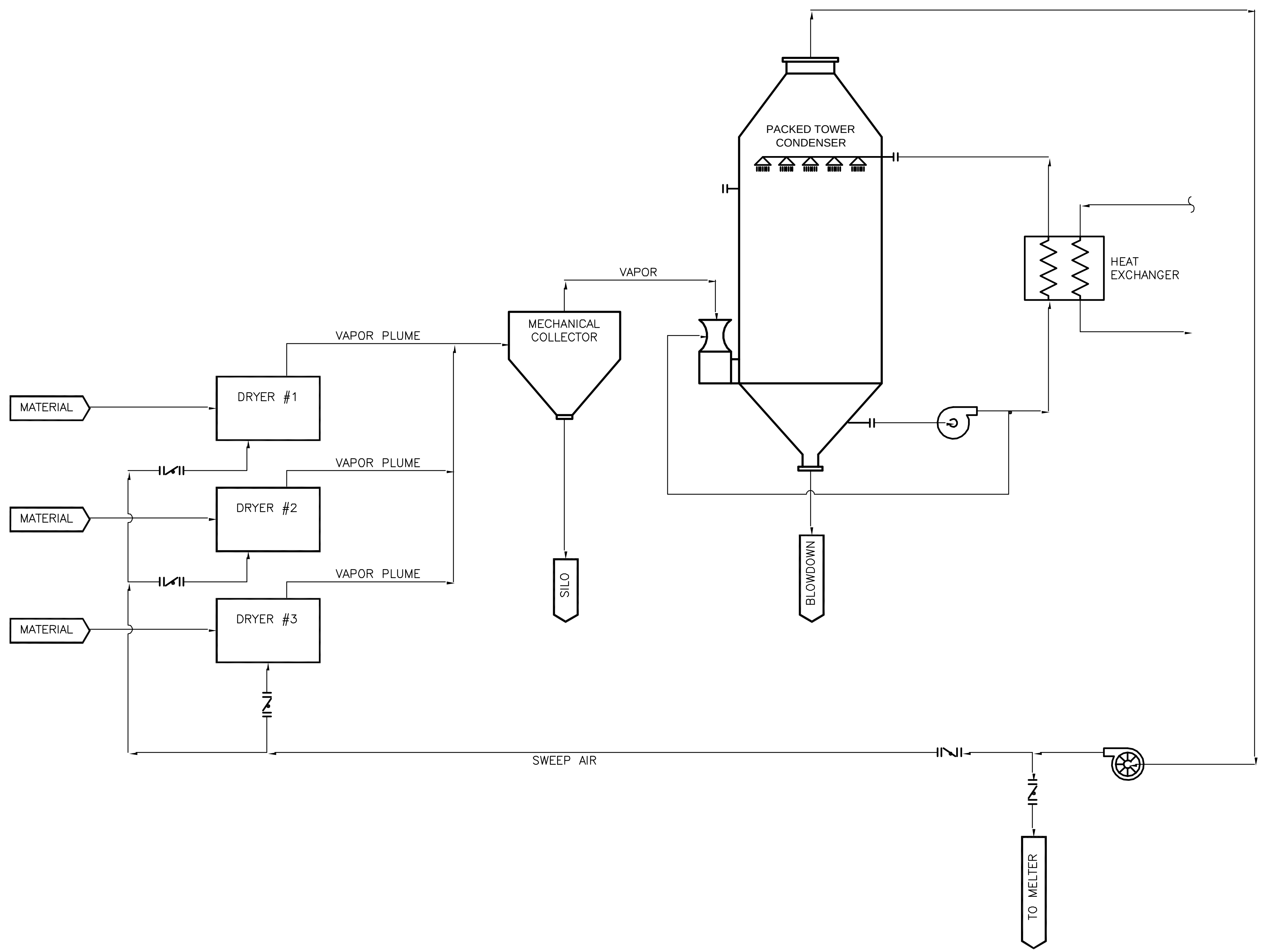
Process Flow Diagram
Melter Exhaust Heat Recovery & AQCE
250 Glass Ton Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No. FVRS-PF-102
Rev. 0



Rev. No.	Revision Description	Date	Drwn.	Chk'd

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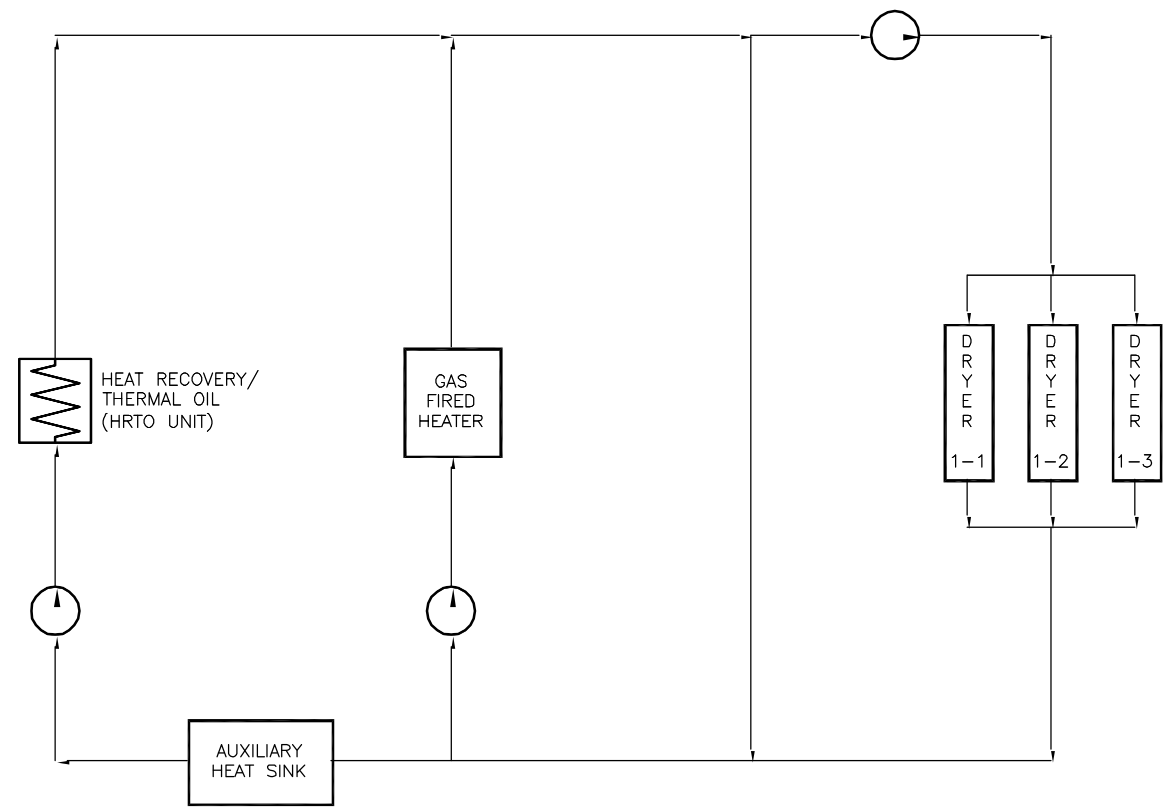
Process Flow Diagram
Dryer Off Gas Treatment
250 Glass Ton Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No.: FVRS-PF-103
Rev.: 0



Rev. No.	Revision Description	Date	Drwn.	Chk'd

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Process Flow Diagram
Thermal Oil Supply System
250 GlassTon Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No.: FVRS-PF-104
Rev.: 0

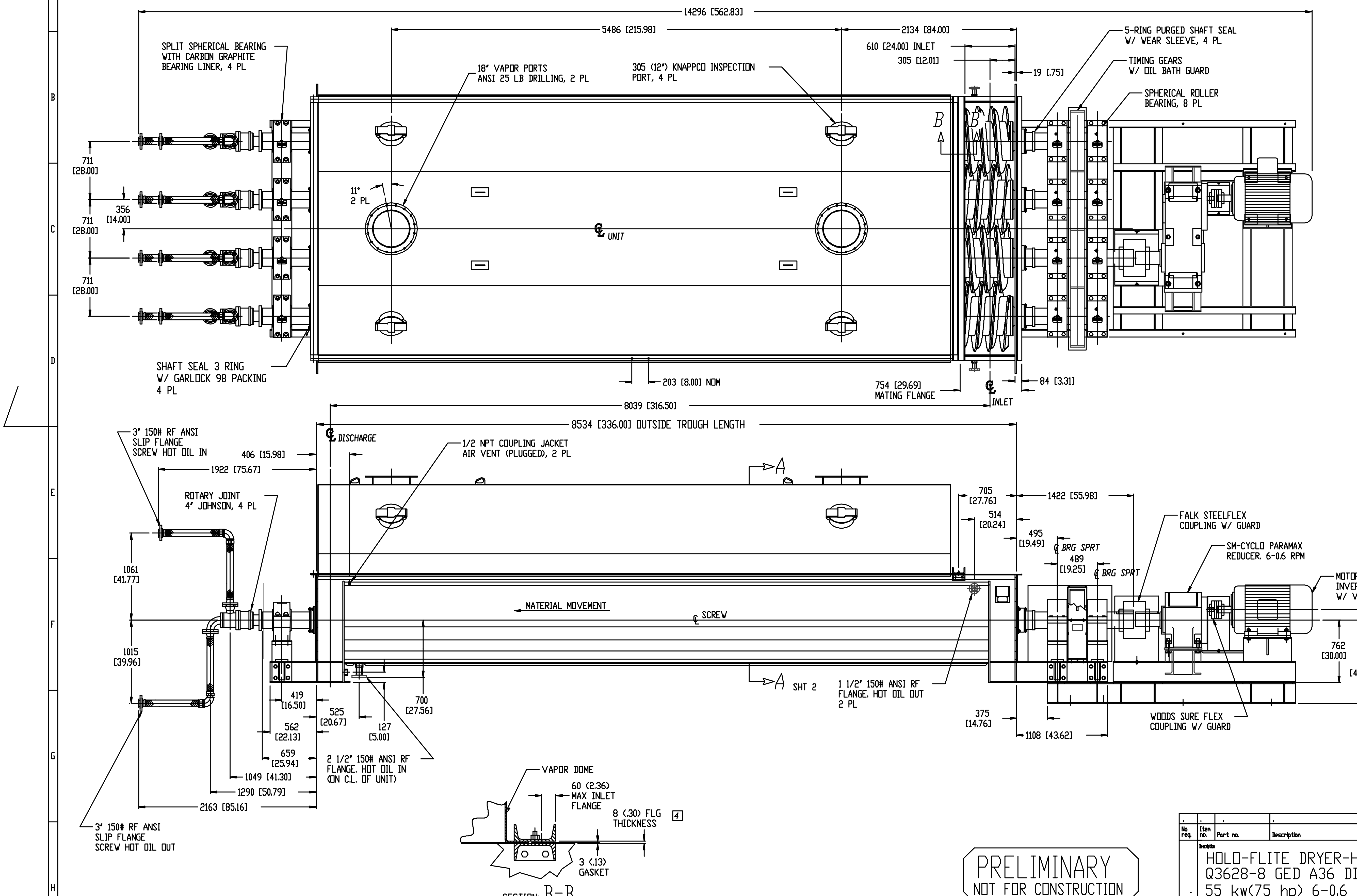
A		INITIAL DRAWING RELEASE

ALL DIMENSIONS ARE MILLIMETERS.

GENERAL ARRANGEMENT DRAWING TOLERANCES, ISO 2768-1, CLASS DESIGNATION COARSE (C)
VALUES SMALLER THAN THOSE LISTED BELOW TO BE NOTED NEAR DIMENSION ON FIELD OF DRAWING.

ALL DIMENSIONS ARE MILLIMETERS.

PERMISSIBLE DEVIATIONS FOR LINEAR DIMENSIONS, BASED ON LENGTH L (mm).										PERMISSIBLE DEVIATIONS FOR EXTERNAL RADII AND CHAMFER HEIGHTS, (mm).			PERMISSIBLE DEVIATIONS OF ANGULAR DIMENSIONS, USE SHORTER SIDE OF THE ANGLE L (mm).				
0.5 ≤L ≤3	3 ≤ L ≤ 6	6 < L ≤ 30	30 < L ≤120	120 < L ≤400	400 < L ≤1000	1000 < L ≤2000	2000 < L ≤4000	4000 < L ≤8000	8000 < L ≤12000	0.5 ≤L ≤3	3 < L ≤ 6	6 < L	L ≤ 10	10 < L ≤50	50 < L ≤120	120 < L ≤400	400 < L
± 0.2	± 0.3	± 0.5	± 0.8	± 1.2	± 2	± 3	± 4	± 5	± 6	± 0.4	± 1	± 2	± 1° 30′	± 1°	± 0° 30′	± 0° 15′	± 0° 10′



PRELIMINARY
NOT FOR CONSTRUCTION

No req.	Item no.	Part no.	Description	Material	Drawing	Mass kg each

Description: HOLO-FLITE DRYER-HOT OIL
Q3628-8 GED A36 DIRECT
55 kw(75 hp) 6-0.6 RPM

Drawn	Date
J. ANDERSON	6NOV01
Checked	Date
D. CLEAR	.
Approved	Date
J. KRAMER	.
Reference Dwg	

Projection: 3rd angle

File name	Scale	Revision
PC1100309-1	1:22	A

Size	Drawing number	Sheet	Cont.
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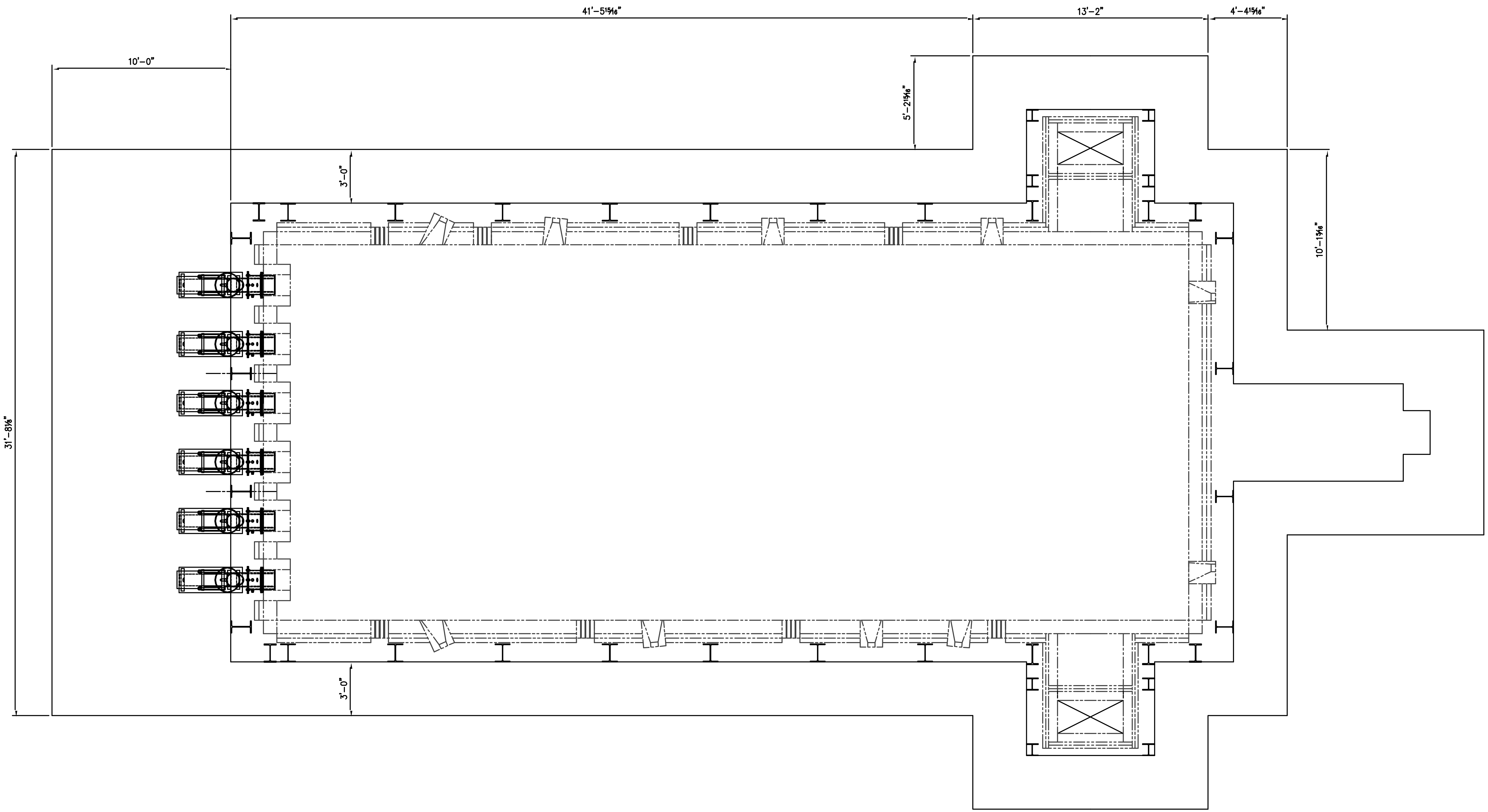

FRAZIER-SIMPLEX, INC. Engineers

ENGINEERS & CONSULTANTS TO THE GLASS & STEEL INDUSTRIES SINCE 1918.

250 TPD
GENERAL ARRANGEMENT
STEEL PLAN VIEW
FOR : MINERGY
WISCONSIN

DRAWN MPH	DATE 6/21/01	FILE	CAD FILE WIQ8596/Q8596-006
ENGINEER	SCALE 3/8"=1'-0"	DRAWING NO.	
CHK'D	CONTRACT 8596		

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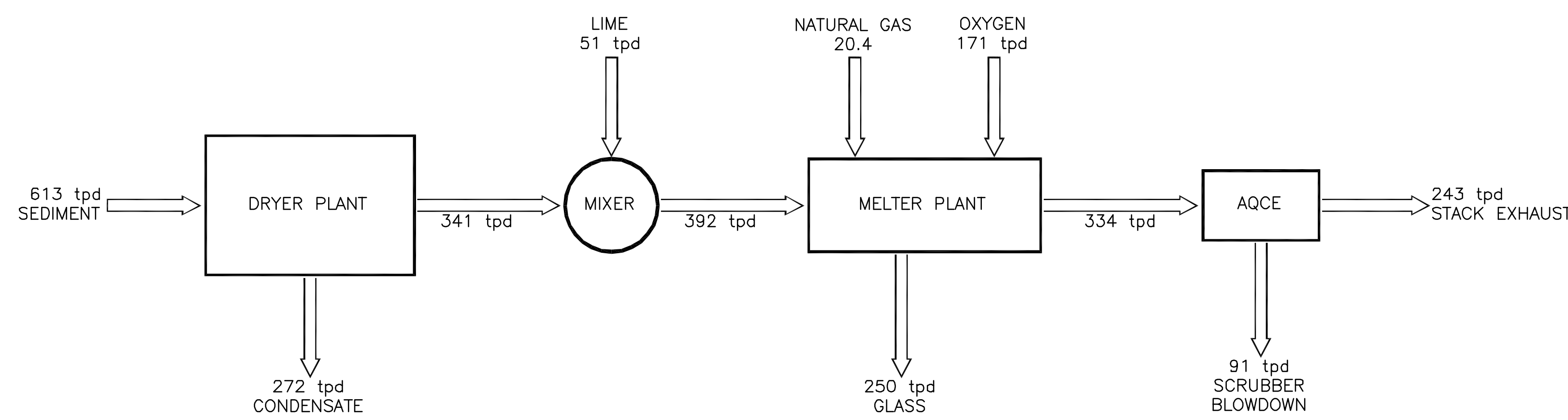

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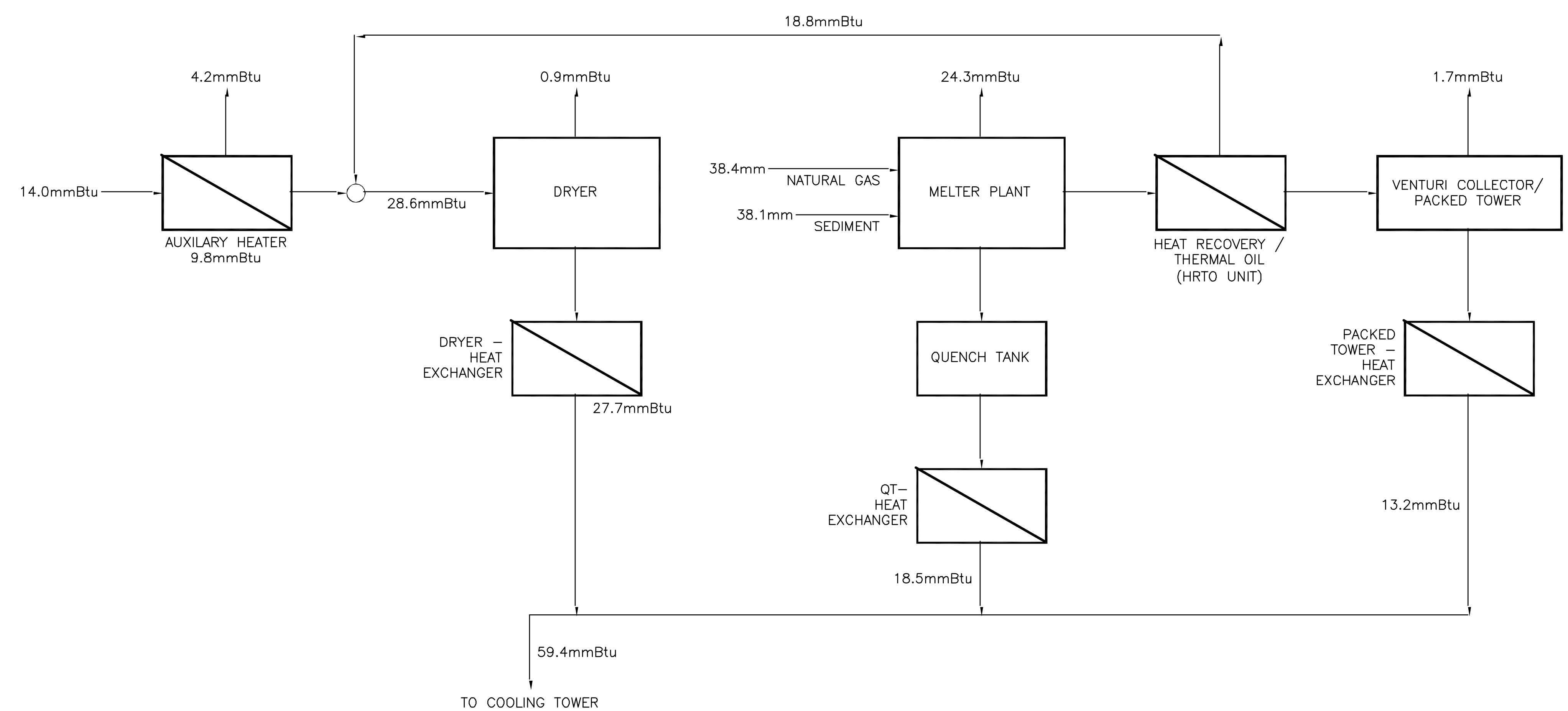
Mass Balance

250 Glass Ton Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No.: FVRS-MB-101
Rev.: 0



Rev. No.	Revision Description	Date	Drwn.	Chk'd

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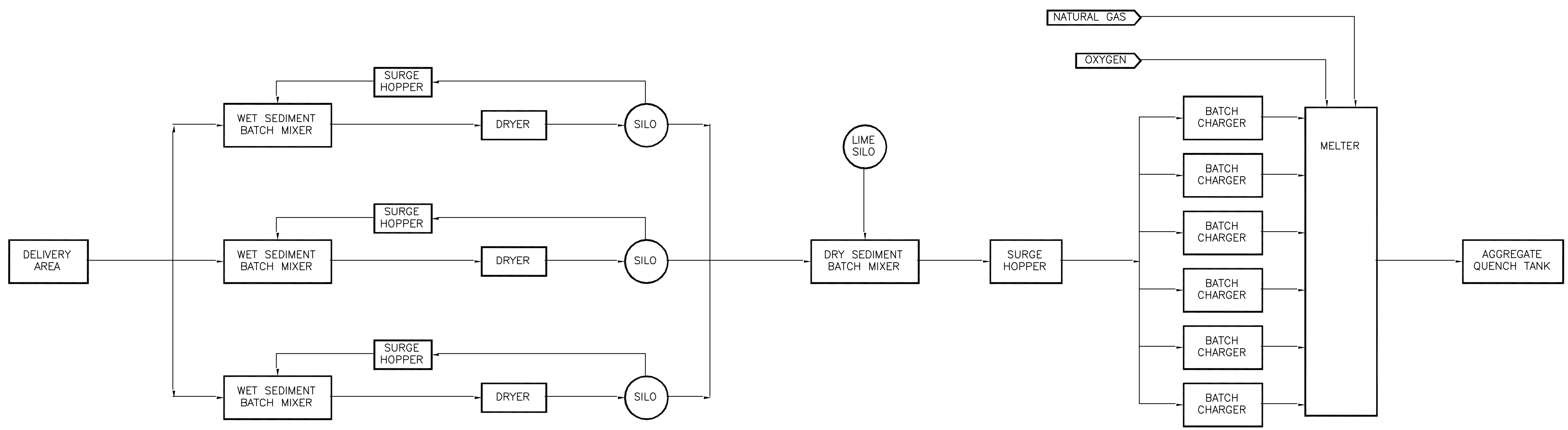
Energy Balance

250 Glass Ton Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No.: FVRS-EB-101
Rev.: 0



LEGEND:

mc = MOISTURE CONTROL
tpd = TONS PER DAY
ts = TOTAL SOLIDS CONTENT

Rev. No.	Revision Description	Date	Drwn.	Chk'd

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Process Flow Diagram
Sediment Drying and Preparation
250 Glass Ton Plant
Fox Valley River Sediment

Date: December 2001
Scale: None
Drawing No.: FVRS-PF-101
Rev.: 0

January 21, 2002

Mr. Robert Paulson
Wisconsin Department of Natural Resources
101 South Webster
P.O. Box 7921
Madison, WI 53707

Dear Sirs:

Subject: Permitting Feasibility – Sediment Melter Plant

Minergy Corp. has performed an analysis regarding the permitting feasibility of a commercial-scale sediment melter.

A full scale 250 glass ton per day melting facility emissions were based on values measured from the demonstration testing. Using good engineering practice, the results were extrapolated to commercial scale, and compared the results against the Wisconsin Administrative Code air regulations (NR400 series).

The expected emissions from a full scale operations would be very low, including a stack-basis destruction of PCBs of greater than 99.9999%. The facility would meet all current air state and federal emissions regulations. The expected annual emissions would not trigger the major source threshold. A discussion of the results of the analysis are listed below.

Background

During the week of August 14, 2001 a project team consisting of the Department, the U.S. EPA, Minergy Corp., Tetra Tech EMI, and EER Environmental conducted demonstration scale testing on a 2 glass ton per day demonstration melter. The project objectives and detailed testing procedures were included by the Quality Assurance and Project Plant (QAPP) which was developed and approved by the USEPA prior to the commencement of the testing.

The primary objective of the testing is “To determine the treatment efficiency (TE) of PCBs in dredged-and-dewatered sediment when processes in the Minergy GFT”. To achieve the objectives the testing included sampling the feed material (contaminated sediment) to the melter, the finished product, and melter stack emissions for PCBs and other Contaminants of Concern (COC’s). Demonstration scale air quality control equipment (AQCE) was also furnished and operated during the testing. The AQCE includes a wet scrubber and a carbon filter.

The data validation was completed by January 5, 2002 and the USEPA has released the data. This letter will review the data, and will make emissions projections to a full scale projection melter. The full scale facility is presently assumed to be a 250 glass ton per day operation. The emissions will be compared to the standards in the Wisconsin administrative code (NR400 series regulations) to determine the feasibility of permitting a full scale facility.

PCB emissions
Exhaust gas emissions were sampled on the demonstration unit before and after the air quality control equipment. PCB concentrations were measured using high resolution gas chromatography / high resolution mass spectrometry. The instrument has the capability of detecting PCBs to extremely low levels. The detection limit for most PCB congeners was 1.00 nanogram (10^{-9} gram). The controlled emissions were measured at an average of 36.6 ng/DSCM.

The full scale unit will have a exhaust gas flow of 4,940 DSCM per hour. The annual PCB emissions in the stack would equate to 1.58 grams per year or 0.0035 pounds per year. This is only 3.5 % of the Wisconsin Administrative Code section NR-445 table 3 values for PCB emissions. In summary, no additional study for the economic and technical feasibility for additional controls will be necessary at this emission level. A full scale facility producing 250 glass tons per day would process 341 tons per day of sediment (dry basis). With an average feed concentration of 28,000 ng/g of total PCBs into the melter the annual input of pure PCBs would be 6,983 pounds. On a stack emission basis this results in a PCB destruction of 99.999949%.

The annual PCB emissions projected above may be over-estimated for at least two reasons. First, during the demonstration, the water cooled extraction probe required frequent manual cleaning, causing a significant risk of contamination. Second, the full scale facility will have a significant increase in exhaust gas residence time over the demonstration scale. The demonstration scale glass melter had an average residence time for the exhaust gases of 2.1 seconds. The full scale is expected to have a residence time of approximately 16 seconds. The additional residence time will tend to increase the destruction of PCBs.

Mercury emissions
Mercury emissions were measured both before and after air quality control equipment. It is clear from the data that mercury removal is occurring in the AQCE equipment. The final melter exhaust emissions were measured at 1.924 ug/DSCM. This equates to 0.1834 lbs/year pounds per year of stack emissions for a full scale unit. The NR446 standard for mercury emissions is expressed as an ambient air concentration of 1.0 ug/m^3, and a mass limit of 3200 grams per day. The expected ambient air concentration for a full scale plant is 0.00011 ug/m^3, and a daily mass emissions of 0.228 g/day. The above ambient air concentrations are based on a 95’ tall stack with a 3’ inside diameter.

Other HAP emissions
The stack was also sampled for Silver, Arsenic, Barium, Cadmium, Chromium, Lead and Selenium. Testing was performed both before and after the AQCE. The above metals were not detected in the exhaust gas stream after the air quality control equipment for all 3 samples taken. It is not expected that the above metals will be an issue in the air permitting process.

Sampling and laboratory analysis for a total of 63 Semi-volatile organic compounds (SVOC) was conduced as part of the demonstration test. USEPA method 10 was used. The only semi volatile compound detected was Benzoic acid. The annual emissions for a full scale unit is projected at 2.37

pound per year. This compound is NOT listed as a hazardous air pollutant under the Wisconsin administrative code.

Sampling and laboratory analysis for a total of 51 specific Volatile organic compounds (VOC's) was conduced as part of the demonstration test. USEPA method 31 was used. None of the 51 specific VOC's were detected on any of the runs.

Sampling and laboratory analysis was also conducted for Polychlorinated Dibenzo Dioxins and Furans (PCDD/Fs). 2,3,7,8-TCDD is listed in the Wisconsin administrative codes hazardous pollutants listing in NR-445. No 2,3,7,8-TCDD was detected in the final exhaust after the air quality control equipment. Some PCDD/F's were detected in the exhaust gases prior to the air quality control equipment, however PCDD/F's were clearly present in the sediment feed material. The dioxin destruction factor on a toxic equivalency (TEQ) basis was 99.9894%. This type of a destruction factor provides a strong indication that post combustion reformation of PCDD/F was not occurring in the process.

NOx Emissions

High temperature thermal processes are usually associated with the formation of NOx (a combination of NO and NO_2.) During the demonstration testing a continuous emissions monitor (CEM) for NOx was connected to the melter exhaust. NOx emissions averaged 2450 ppmdv during the duration of the testing. The designers of the demonstration melter have seen a strong correlation between NOx emissions and melter scale up, with NOx emissions decreasing as melter capacity increases. At this time, the supplier estimates full-scale emissions of 1200 ppmdv. The resulting annual emissions will be 109.4 tons per year. This quantity is below the major source threshold of 250 tons per year established in chapter NR405 of the State regulations. If it is later determined that the emissions are not acceptable, additional end of pipe controls can be added to reduce NOx emissions by up to 90%.

SO_2 emissions

Traces of sulfur can be found in the dredged sediment. The sulfur is converted to SO_2 in the high temperature oxidizing environment inside the melter. During the demonstration testing a continuous emissions monitor (CEM) for SO_2 was connected to the melter exhaust. The efficiencies of SO_2 control equipment are well established and are accepted by the USEPA and WDNR. The expected full scale facility SO_2 emissions are 44.41 tons per year assuming a typical wet scrubber with 93% removal efficiency. This quantity is below the major source threshold.

CO emissions

The production of CO is associated with the incomplete thermal oxidization of organic materials. During the demonstration testing a continuous emissions monitors (CEM) for CO was connected to the melter exhaust. The CO emissions during the demonstration test were 3.3 ppm. The expected full scale facility CO emissions are 0.18 tons per year. This quantity is below the major source threshold.

VOC emissions

Much like CO the production of VOC's (Volatile Organic Compounds) is associated with the incomplete thermal oxidization of organic materials. During the demonstration testing a continuous emissions monitor (CEM) for VOC's was connected to the melter exhaust. This emissions monitor detects all VOC's; however, it is unable to identify specific compounds like USEPA method 10 and 31 discussed in the HAP Emissions section above. The VOC emissions during the demonstration test was 2.3 ppm. The expected full scale facility VOC emissions are 0.07 tons per year. This quantity is below the major source threshold.

Particulate Matter

Equipment vendors guarantee 0.01 grain per DSCF of exhaust gas for particulate control equipment. The resulting full scale emissions result in 1.09 tons per year. This quantity is below the major source threshold.

Summary of Emissions

The following is a summary of emissions from a 250 glass ton per day river sediment melter exhaust.

Air pollutant	Annual potential to emit	Unit of measure
Particulate	1.09	Tons per year
Sulfur dioxide	44.41	Tons per year
Organic compounds	0.07	Ton per year
Carbon monoxide	0.18	Ton per year
Nitrogen oxides	109.4	Tons per year
Mercury	0.183	pound per year
PCBs	0.0035	pound per year

Conclusion

A commercial-scale sediment melter facility appears to be fully permittable under Federal and Wisconsin regulations.

Please contact me at (920) 727-1411 if you have any questions.

Sincerely,

Terrence W. Carroll
Regional Manager