

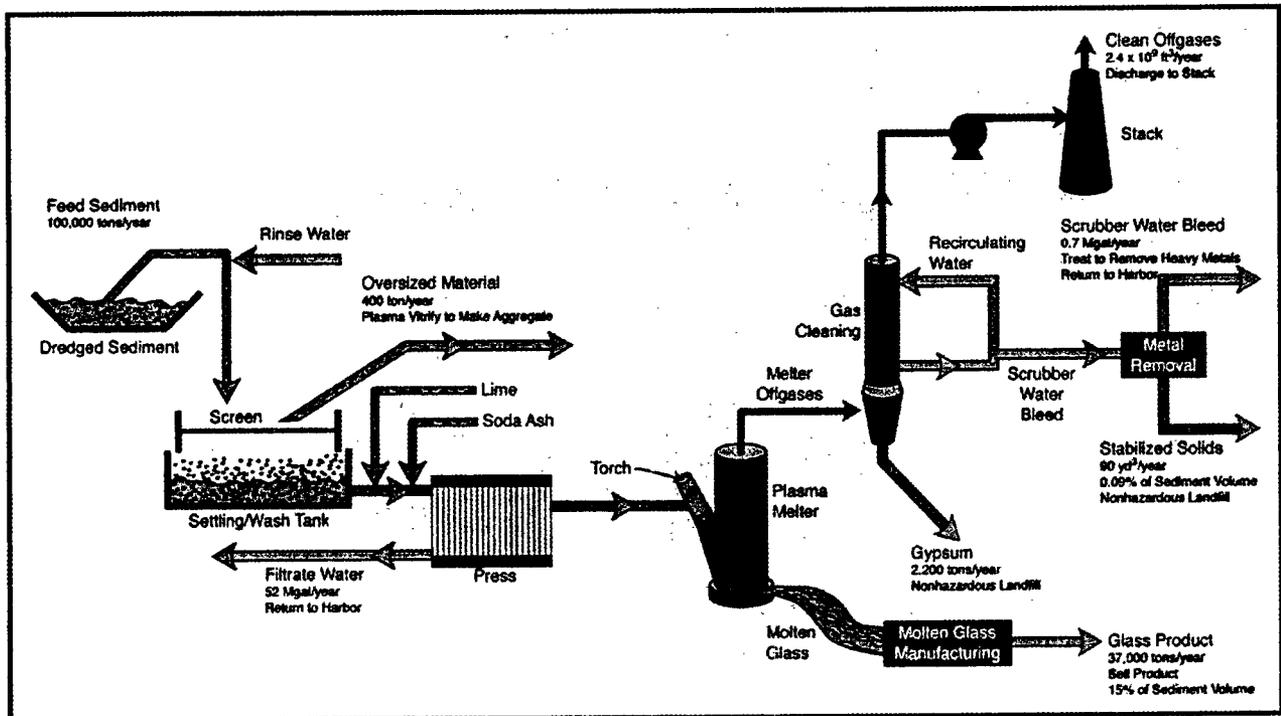
# Final Phase II Pilot-Scale Testing Report

## Decontamination of Dredged Estuarine Sediments from New York/New Jersey Harbor: The Westinghouse Plasma Vitrification Process

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## ABSTRACT

Westinghouse Science and Technology Center (WSTC) has completed a five-month, Phase II Pilot Program to test an integrated plasma vitrification process for decontaminating New York/New Jersey Harbor sediment while producing a glass with potential commercial value. The Phase II Pilot Tests were supported by Contract 725024 from Brookhaven National Laboratory. Phase II Pilot Tests of the plasma vitrification process were performed at Westinghouse's Plasma Test Facility located at the Waltz Mill Site near New Stanton, Pennsylvania.

The Phase II Pilot Program demonstrated the critical elements of a Plasma Vitrification Treatment Train by processing 18 tons of sediment at a processing rate equivalent to 0.8 ton/hour of dredged material. The pilot tests successfully decontaminated harbor sediment dredged from Newtown Creek, producing 3500 lb of glass from the sediment's silica mineral content, and minimizing waste from the process sidestreams.

Results of the Phase II Pilot Program are being used to develop a preliminary design for a 500,000 cy/year sediment decontamination facility, and to determine in greater detail the economics of the process.

## ACKNOWLEDGEMENTS

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Westinghouse contracted Severson Environmental Services, Inc. of Niagara Falls, New York, to perform the sediment pretreatment tests for this Phase II Pilot Program. Mr. Michael Crystal's expertise in sediment handling and dewatering significantly contributed to the pilot program's success.

Within Westinghouse, the program was performed by the WSTC Plasma Test Facility personnel directed by Dr. Shyam Dighe. Mr. William Gass was the test engineer. The test program's success resulted from the coordinated efforts of the entire Plasma Center staff, especially Steven Krocsko, Glenn Wentzell, Dennis Hough, Irvine Phipps, Carl Robaugh, and Mark Darr. Finally, we acknowledge the continued WSTC program support of Dr. Dale Keairns, Manager of Chemical and Environmental Technologies, and Mr. Howard Shaffer, Program Development Manager.

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## 1. EXECUTIVE SUMMARY

The Westinghouse Science & Technology Center (WSTC) completed a five-month, Phase II Pilot Program to test an integrated plasma vitrification process (Figure 1.1) for decontaminating New York/New Jersey Harbor sediment. The vitrification process decontaminates the sediment (i.e., 99.9999% hazardous organic destruction is achieved in the plasma reactor), produces a product glass from the sediment's quartz mineral content, and minimizes waste (i.e., the volume of all contaminated, solid waste streams is reduced to 0.1% of the dredged sediment volume).

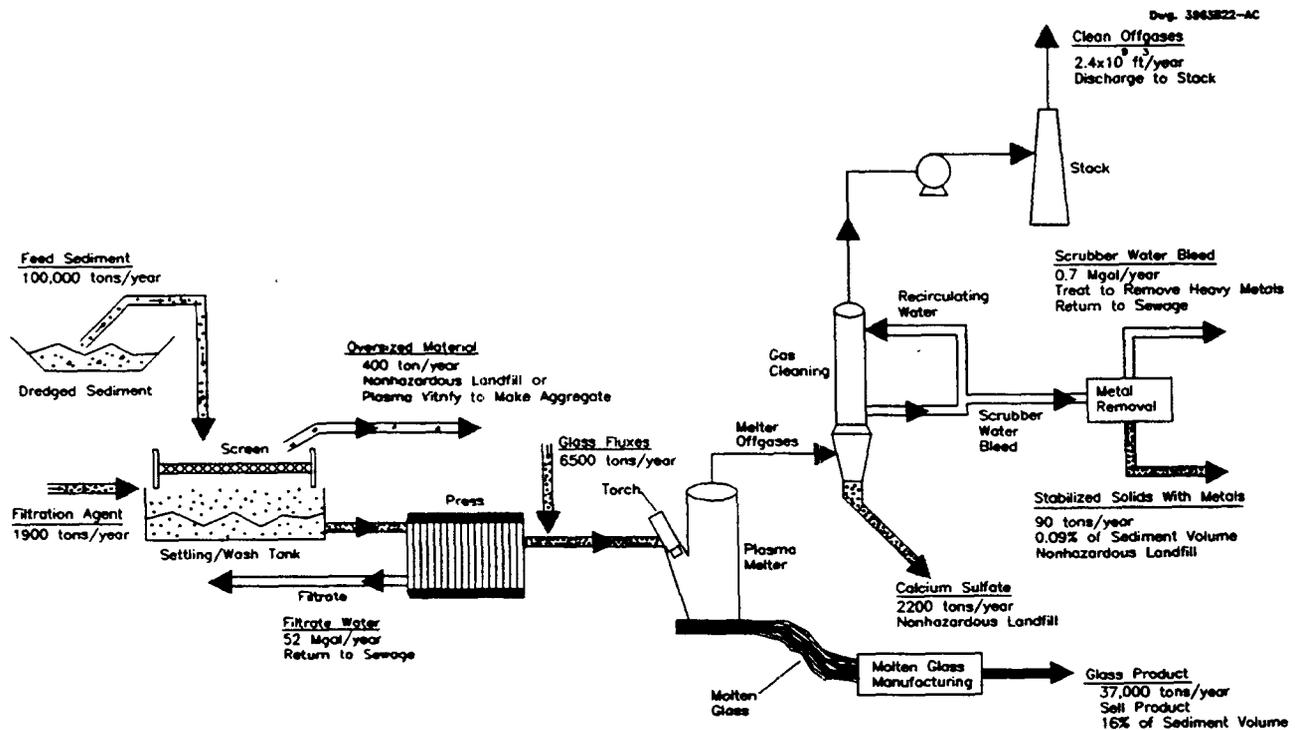


Figure 1.1 The Integrated Westinghouse Plasma Vitrification Treatment Train

The driving engine of Westinghouse's treatment train is the plasma melter. The sediment is melted in the plasma melter using fluxes to produce a target glass product. The molten glass can be quenched to produce a glass aggregate or directly fed to glass manufacturing equipment to provide a salable commercial glass

product. In the plasma melter, all organics are dissociated into elemental species which form clean gases (i.e., N<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>O, and CO<sub>2</sub>) that meet environmental release standards. Hazardous metals are incorporated into the product glass where they become environmentally benign. The dredged sediments are pretreated to optimize the integrated treatment train's economics and control the glass product quality. The integrated treatment train will be designed to minimize all process residuals, and ensure an environmentally acceptable solution.

Phase II Pilot Tests of the plasma vitrification process were performed at Westinghouse's Plasma Test Facility located at the Waltz Mill Site near New Stanton, Pennsylvania. The Phase II Pilot Program demonstrated the critical elements of this Plasma Vitrification Treatment Train by processing 17.5 tons of sediment at a processing rate equivalent to 0.8 ton/hour of dredged material. The Phase II Pilot Tests provide the design basis needed in order to proceed with an integrated treatment train design. Results of the Phase II Pilot Program indicate that the Westinghouse Plasma Vitrification Process is a viable solution to the New York/New Jersey Harbor Sediment problem.

Westinghouse is prepared to proceed in taking the plasma vitrification process forward through demonstration and full-scale operation. Westinghouse has assembled an experienced team that has successfully developed and commercialized the key technologies proposed for sediment processing for related applications. The Westinghouse team — lead by the Westinghouse Science & Technology Center — brings together years of vitrification experience applied to DOE waste problems, commercial plasma processing experience, waste processing expertise, and knowledge of commercial glass formulation. Westinghouse has developed relationships with environmental companies and glass manufacturers to secure the needed experience in sediment pretreatment and glass manufacturing. The team's technical understanding and commercialization experience will result in the efficient implementation of the proposed program to develop a cost-effective commercial solution for decontaminating Harbor sediments.

## **1.1 WESTINGHOUSE PROGRAM OBJECTIVES**

Westinghouse's objective is to demonstrate an economically attractive clean technology that produces a useful product from contaminated sediment while minimizing the environmental impact of decontamination operations. In order to provide an effective solution to treatment of contaminated harbor sediments:

***1. The proposed process must be at a state of development that allows implementation in a time frame that solves the Harbor sediment problem.*** The decontamination solution must move quickly through pilot and demonstration phases into commercialization in order to solve the Harbor's pressing need to find a sediment decontamination solution.

The Westinghouse Plasma Vitrification System is a proven technology for vitrifying waste. The two major operations in the Westinghouse Plasma

Vitrification Process treatment train, sediment pretreatment and plasma melting, are commercially proven operations. A commercial plant could be operational in a two year period.

- The Plasma Vitrification Process has an inherently high throughput and is readily scaleable to the production levels required of 100,000 cy/year and 500,000 cy/year.
- The Westinghouse Plasma Melter is the basis for the vitrification process proposed for decontaminating sediments dredged from the New York/New Jersey Harbor. The Plasma Melter is in use commercially, operating at 300,000 ton/year throughput, a rate within the range expected to be used for sediment processing. In addition, a one million ton per year plasma-fired melter is being commissioned at a large domestic steel mill.
- The unit operations selected for the integrated plasma vitrification process have been proven in other waste-processing applications.
- Auxiliary systems such as solids feeders, power supplies, control systems, glass-pouring systems, and refractory have been demonstrated in a wide variety of applications in commercial practice.
- Westinghouse has extensive experience in developing integrated waste remediation and management solutions, and has experience in all of the potential decontamination processes; Westinghouse, therefore, fully understands the issues and tradeoffs involved in selecting a decontamination process.
- Westinghouse has successfully demonstrated a transportable system for liquid PCB destruction and tested the plasma concept at pilot scale for processing PCB-contaminated solid materials and hazardous solid-liquid wastes, minimizing both the technical risk and the issues associated with scaleup.
- Westinghouse has commercially implemented the type of preprocessing needed for the Harbor decontamination process in its soil-washing projects, such as the remediation of a 20,000-ton uranium-mining site.
- Westinghouse subcontracted pretreatment dewatering operations to Severson Environmental, Inc. a company with extensive commercial experience in dewatering sediments and petroleum oil sludges.
- Westinghouse is a leader in offgas cleaning. Operational experience in hazardous waste incinerators and municipal waste incinerators combines with product development experience in hot gas filtration for the power generation industry, to ensure the ability to design environmentally effective offgas cleaning systems.

**2. The decontamination process must produce a minimum amount of secondary waste.** The New York/New Jersey Harbor Areas has limited space for waste disposal. An important criteria for any process will be that the process minimizes waste produced. Secondary waste treatment from separations in decontamination technologies often produce significant waste to be landfilled.

The Integrated Plasma Vitrification process is a minimized waste approach to harbor sediment treatment.

- All sediment contaminants can be processed in the integrated plasma vitrification system.
- The process produces stable, low-leachability glass as the product, which is usable for general purpose applications.
- The Westinghouse Plasma Vitrification Process reduces the volume of total solids by more than 80%, most of these solids are useful glass building materials.
- The Westinghouse Plasma vitrification process reduces the volume of contaminated waste by 99.9%. We estimate that a total volume of 90 cy/year of stabilized hazardous metals will need to be landfilled from a plant processing 100,000 cy/year of sediment.

**3. The proposed process must provide a cost effective solution to the harbor decontamination problem.** The New York/Jersey Harbor needs to be dredged to provide navigable waterways. Estimated volumes of up to 4 million cy/year of Category III contaminated sediments cannot be ocean dumped. There are limited options for disposing this sediment in an economical fashion. Treating massive volumes of sediment becomes prohibitively expensive unless the process is economically comparable with near term storage options.

- The Westinghouse Plasma Vitrification Process has an attractive economic potential. The large-scale, high throughput, relatively simple plasma vitrification system becomes economically advantageous in the New York/New Jersey area where 1) area electrical costs are low and 2) processing cost can be offset by the sale of a high-value glass product produced from the process.
- The process is economical by comparison with other decontamination options. Process operating costs will be below \$100/ton, before taking any credit for the value of the end-product material.
- The process has the potential to produce useable construction materials, aggregate, roofing granules, or glass fiber products with potential values up to \$500/ton. This reduces the processing cost by as much as \$150/ton.

**4. The process must produce a useful product from the sediment materials.** Westinghouse has demonstrated in the Phase II pilot tests that the sediment can be used as the primary feedstock to produce glass with a durability and composition that can be used to manufacture useful building materials.

## **1.2 PHASE II PILOT TEST PROGRAM RESULTS**

The Phase II Pilot-Scale Program demonstrated an economical, integrated system design and validated the ability to produce glass using a plasma torch fired system at a scale that is representative of demonstration and commercial operations. The Phase II program met its program objectives by:

- Confirming the plasma reactor design and operating conditions while processing 17.5 tons of Newtown Creek sediment to demonstrate the crucial technology components of the integrated plasma vitrification treatment train. Sediment size segregation, rinsing, dewatering, plasma vitrification, and scrubber water treatment were all successfully demonstrated.
- Demonstrating essentially complete, 99.9999%, destruction of organics in the sediment.
- Demonstrating hazardous metal incorporation into the product glass; 80% of the hazardous metals were incorporated in the product glass. Leaching tests on the glass product show that the glass passes TCLP leach criteria by several orders of magnitude.
- Confirming the pretreatment system design and the filtrate water stream's composition. Sediment was successfully dewatered to 58% solids; the filtrate water's composition meets discharge criteria.
- Establishing the off-gas compositions, providing the basis for commercial offgas treatment system design. Melter offgases were directly sampled before gas cleaning. Offgas SO<sub>x</sub>, NO<sub>x</sub>, particulate, organic, and metal compositions provide the basis for a commercial gas cleaning system design.
- Generating glass product of the target characteristics, allowing an assessment of glass product manufacturing options. Two potential glass products, fiber glass and glass tile, have been identified as candidates for manufacture. Both have high product values, up to \$500/ton, and large markets that will not be saturated by the sediment decontamination plant.
- Confirming the environmental acceptability of process output streams. The decontamination facility minimizes waste produced. Phase II Pilot Test sample analysis confirm that all waste streams will be environmentally acceptable.

### **1.3 PHASED APPROACH TO INTEGRATED TREATMENT TRAIN DESIGN**

The information needed to design the integrated plasma vitrification process is being developed in several phases. The three major phases for developing the design information are the Phase I Bench-Scale Tests completed in the last quarter of 1995, the Phase II Pilot Tests completed in December of 1996, and the Preliminary Design Phase following the Phase II Pilot Program to develop a specific design for full-scale operation. Table 1.1 summarizes the design objectives for each processing unit in each of three phases of the treatment train development.

In Phase I Bench-Scale Program, feasibility testing showed that a glass product could be made using the sediment as a feedstock. Sediment characteristics of importance to the process development were determined. Phase I testing determined possible glass compositions obtainable using the sediment. The Phase I bench scale tests did not, however, use a plasma torch to dissociate organics.

The Phase II Pilot Test Program demonstrated the formulation of glass product in a pilot plasma unit that is readily scaleable to demonstration and commercial scales. The Phase II Pilot Tests demonstrated sediment sizing, rinsing, dewatering, and plasma melting operations. Remaining treatment train unit operations (i.e., gas cleaning) will be specified using data collected in the pilot tests. The Phase II pilot test program provides the information needed to set design parameters on any auxiliary operations in the treatment train, sediment pretreatment and gas cleaning. These components of the treatment train are commercially available. Their specification requires, however, the pilot test data on input stream characteristics. With input streams characterized in Phase II, the treatment units can be designed, and quotes can be obtained for the components from commercial vendors.

Glass manufacturing was not piloted in Phase II. Westinghouse is currently working with several glass manufacturers to identify viable commercial glass products.

Westinghouse is proceeding with the Preliminary Design Phase using the results of the Phase II Program to develop a process flow diagram, specify equipment, and develop a capital cost for the integrated sediment decontamination plant.

### **1.4 REPORT ORGANIZATION**

This report is organized in the following manner. Section 2 summarizes background information on the program including a brief description of the Harbor sediment problem (Section 2.1) and the proposed Westinghouse solution (Section 2.2). The overall program objectives for Westinghouse's New York/New Jersey Harbor sediment decontamination program are presented, Phase I Bench Scale results are summarized, and specific objectives for this Phase II Pilot Testing Program are reviewed.

Table 1.1 Westinghouse's Phased Approach to Design Development

TREATMENT UNIT	OBJECTIVES
<b>PHASE I BENCH-SCALE TESTS</b>	
Plasma Melter	<ul style="list-style-type: none"> <li>• Characterize sediment (mineralogy, physical and chemical characteristics)</li> <li>• Define a glass melt recipe</li> <li>• Demonstrate ability to make target glass</li> <li>• Demonstrate that glass is nonleachable</li> </ul>
Sediment Pretreatment	<ul style="list-style-type: none"> <li>• Pretreat sediment to supply feed for melting</li> <li>• Confirm that chlorine is readable rinsed from sediment</li> <li>• No testing to define pretreatment equipment</li> </ul>
<b>PHASE II PILOT TESTS</b>	
Size Segregation	Demonstrate with pilot/commercial equipment
Sediment Rinsing/Dewatering	<ul style="list-style-type: none"> <li>• Define specific process design</li> <li>• Select dewatering technique (centrifugation, filtration)</li> <li>• Determine what additives will be used, if any (lime, polymers)</li> <li>• Define performance obtainable</li> <li>• Demonstrate with pilot equipment</li> <li>• Determine rinse water characteristics and treatment requirements, if any</li> </ul>
Plasma Melter	<ul style="list-style-type: none"> <li>• Demonstrate organic dissociation</li> <li>• Define plasma melter design (feedrate, torch power, residence time,)</li> <li>• Establish melter performance</li> <li>• Demonstrate with pilot scale equipment</li> <li>• Determine metal partitioning</li> <li>• Determine scrubber water characteristics and treatment requirements, if any</li> </ul>
Glass Manufacture	Demonstrate composition of a viable commercial product
Gas Cleaning	<ul style="list-style-type: none"> <li>• Meet pilot emission standards</li> <li>• Determine offgas contaminant concentrations (metals, SO<sub>x</sub>, NO<sub>x</sub>)</li> </ul>
Scrubber Water Treatment	<ul style="list-style-type: none"> <li>• Define scrubber water characteristics and need for treatment</li> </ul>
Integrated System Issues	<ul style="list-style-type: none"> <li>• Define optimum feed moisture content</li> <li>• Define optimum recycle rate of water quench stream</li> <li>• Produce flow diagram of processing steps for the integrated system</li> </ul>
<b>CONCEPTUAL/PRELIMINARY DESIGN PHASE</b>	
Integrated System	<ul style="list-style-type: none"> <li>• Develop plant design basis ( plant capacity, load follow)</li> <li>• Develop process flowsheet and P&amp;ID</li> <li>• Develop equipment list</li> <li>• Specify major equipment</li> </ul>
Glass Manufacture	<ul style="list-style-type: none"> <li>• Identify glass product</li> <li>• Test manufacturing feasibility (not currently funded)</li> </ul>
Gas Cleaning	Design gas cleaning system
Scrubber Water Treatment	Design scrubber water treatment system

Section 3 presents the conclusions and recommendations obtained from the Phase II Pilot Test Program.

Details on the Phase II Pilot Test Program are provided in the Sections 4 through 11. Section 4 describes the pilot unit in which Phase II tests were performed. Section 5 reports on all sediment pretreatment operations. Section 6 presents the results of sediment vitrification, melting, operations. The overall material and energy balance for the Phase II Pilot Tests is then presented in Section 7. Section 8 summarizes the Phase II Pilot Test decontamination results. The current status of glass product development is summarized in Section 9. The energy requirements obtained from the Phase II tests, the basis for scaled energy balances, is reported in Section 10. The environmental impact of all process output streams, including the characterization of these streams from the Phase II Pilot Tests, is discussed in Section 11.

A description of production-scale (100,000 cy/yr) and full-scale (500,000 cy/yr) designs for a sediment decontamination facility is presented in Section 12. This section uses Phase II results to update the designs. Capital and operating costs for production- and full- scale designs are developed from the current design base. The plant design will be updated as a preliminary design is developed for the sediment decontamination plant. Capital and operating cost estimates will also be refined in the preliminary design phase, currently in progress.

## **2. BACKGROUND**

Background on the sediment decontamination problem and the Westinghouse technical solution, including a summary of Phase I Bench Scale test results and the Phase II Pilot Test program objectives, are provided in this section.

### **2.1 THE HARBOR SEDIMENT PROBLEM**

The problem of sediment accumulation in the New York/New Jersey Harbor and the economic implications that may result if the situation is not corrected is pressing. Current environmental regulations impacting dredging and disposal of Harbor sediment are outlined below, along with alternatives being considered for safe and economical disposal of contaminated sediment.

#### **2.1.1 Accumulation of Sediments in New York/New Jersey Harbor**

The port of New York/New Jersey receives more tonnage than all other ports in the United States with the exception of New Orleans. Some 4500 ships pass through the Harbor annually. Import-exports moving through this port in 1993 totaled 40,700,000 tons, with a monetary value of over \$20 billion. Maintaining the Harbor is critical to the local economy, supporting 200,000 jobs in the New York/New Jersey area. Furthermore, loss of Harbor facilities would have an impact throughout the United States, since a large portion of any relocation would likely be to Halifax and other foreign ports.

Sediments from the New York/New Jersey Harbor (Harbor), shown in Figure 2.1, must be routinely dredged to maintain navigable water depths for safe navigation. The average natural depth in the Harbor is approximately 19 feet, while incoming ships require depths in excess of 40 feet. Recent proposals call for deepening existing channels to 50 feet to accommodate larger ships. Sediments are continuously transported into the Harbor from the various rivers feeding the bay, including the Hudson, the Passaic, and the Hackensack Rivers. To maintain navigable passage through the Port region, the U. S. Army Corps of Engineers (COE) has built and maintains 240 miles of waterways. The COE must remove some 5 million cubic yards (MCY) of sediment annually to keep these Federal navigation channels operational. Another 2 million cubic yards are dredged annually by private applicants. As of July 1995, there was a backlog of 7.6 million cubic yards of sediment awaiting dredging and disposal.

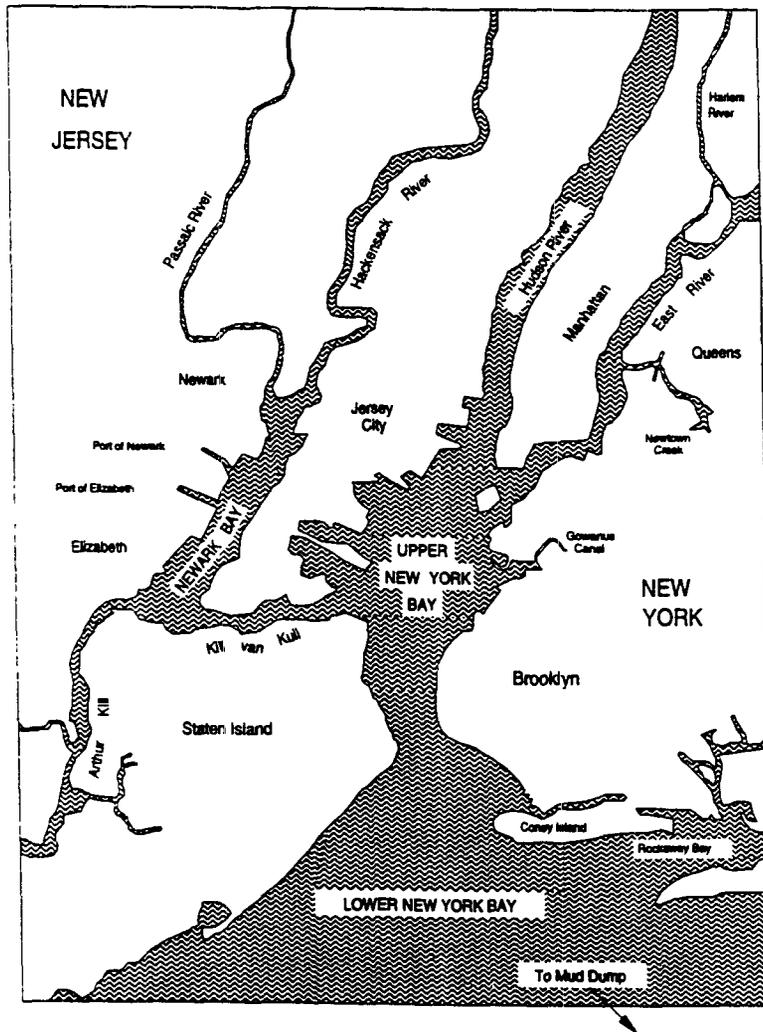


Figure 2.1 Map of New York / New Jersey Harbor Area

Ocean disposal has been used as the primary alternative for disposal of dredged materials. Since 1977, materials have been transported offshore into the New York Bight six miles east of Sandy Hook and eleven miles south of Rockaway, New York, to an area called the New York Dredged Material Disposal Site or the "Mud Dump Site".

### 2.1.2 The Issue of Sediment Contamination

The sediments consist primarily of fine sand and silt, with some natural organic material. The sediments that accumulate in the Harbor may, however, contain contaminants such as organic compounds from oil spill residues, toxic organics from industrial discharges, and heavy metals, frequently at high enough concentrations to prohibit direct ocean disposal. The 1994 EPA Contaminated Sediment

Management Strategy<sup>a</sup> defines contaminated sediments as those materials “which contain chemical substances at concentrations that pose a known or suspected threat to aquatic life, wildlife, or human health.” Much of the sediment quality in the Harbor is poor, due to pollutant inputs from the watershed, atmospheric deposition, wastewater discharges, and combined sewer overflows. Although much progress has been made in the reduction of point sources of new pollutant, large inventories of toxic materials still exist which feed into the Harbor, especially sewage residues in the Gowanus Canal, industrial and petroleum wastes in Newtown Creek, and a variety of industrial sites along the Passaic River including the former Diamond Alkali agent orange manufacturing facility

Sediments have been classified since 1977 by the Marine Protection Research and Sanctuaries Act (MPRSA) implementation manual (or “Green Book”)<sup>b</sup> according to their degree of contamination. Three classifications were established, as shown in Table 2.1. Revisions to the Green Book in 1991 increased analytical sensitivity of detection limits, augmented the number of chemicals to be tested for, and added other biological testing assays.

Table 2.1 Sediment Disposal Category Descriptions

CATEGORY	TEST RESULT CHARACTERISTICS	DISPOSAL IMPLICATIONS
I	Does not cause unacceptable toxicity or bioaccumulation in biological test systems.	Should always be used for beneficial purposes; suitable for unrestricted ocean disposal. Coarse grain sand may be used for beach nourishment; coarse and fine grain material may be used as an interim or final cap at borrow pits or Mud Dump Site; may be used for cover at historical disposal areas.
II	Does not meet criteria for unrestricted ocean disposal but does not pose a definite threat of mortality.	Suitable for ocean disposal with capping; suitable for disposal at landfills, borrow pits and containment facilities, or as daily or interim landfill cover.
III	Fails to meet ocean dumping criteria.	Not suitable for ocean disposal; suitable for disposal at containment facilities and borrow pits, or as sanitary landfill cover.

Preliminary testing at that time indicated that up to 40 percent of Harbor sediment would classify as Category III and therefore be unsuitable for ocean disposal. Table 2.2 indicates estimated annual volumes of New York/New Jersey Harbor sediments which will require disposal, developed by two estimation methods. A further complication was the presence of dioxin in many sediments,

<sup>a</sup> U. S. Environmental Protection Agency, “1994 EPA Contaminated Sediment Management Strategy”, EPA 823-R-94-001, 1994

<sup>b</sup> U. S. Army Corps of Engineers and U. S. Environmental Protection Agency, “Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters: Implementation Manual for Section 103 of Public Law 92-532 (MPRSA)”, 1992.

Table 2.2 Estimated Volume of Sediment for Disposal

Category	Method 1 (MCY)	Method 2 (MCY)
I	2.4	2.5
II	1.9	3.4
III	2.8	1.8

especially in areas of heavy industrial use, and growing concern over disposal of Category II materials in the ocean.

The Marine Protection, Research, and Sanctuaries Act, part of the Clean Water Act, requires that ocean dumping be evaluated by the EPA. Accordingly, EPA has established criteria for ocean dumping. Dredged sediments must pass specific chemical and biological test criteria prior to ocean disposal. The criteria are currently discussed in "Guidance for Performing Tests on Dredged Materials Proposed for Ocean Disposal".<sup>a</sup> One class of contaminants of concern are the dioxins, some members of which (in particular 2,3,7,8-TCDD) are extremely toxic at very low concentrations. The criteria currently limit disposal of dredged material that contain detectable (about 1 ppt) levels of dioxins or that show accumulation in robust organisms, particularly sandworms (i.e., *nereis virens*), of 1 ppt dioxins in 28 day tests. Specific sediment concentration criteria and biological testing are being developed for other target toxic substances (for example lead, mercury, arsenic, and cadmium).

### 2.1.3 Sediment Disposal Options

A variety of disposal options that exist for Harbor sediments are summarized in Table 2.3. Ocean disposal remains an option only for Category I material, and may only be available for this material for a limited period of time. The cost based on USCOE estimates is low, ranging from \$5 to \$12/cy for Category I and \$20 to \$41/cy for Category II with capping.

Subaqueous pit containment facility disposal involves placing the contaminated sediment in existing depressions in the bottom of the Harbor. Most existing "borrow pits" are the result of historical sand and gravel mining operations, with a few natural depressions. In this option, dredged sediment would be deposited in the pit to within a few feet of the prevailing depth outside the pit, and then capped with Category I material. USCOE cost estimates for this option range from \$5 to \$9/cy,

<sup>a</sup> Guidance for Performing Tests on Dredged Materials Proposed for Ocean Disposal, U. S. Army Corps of Engineers (New York District) and U. S. Environmental Protection Agency (Region II), September 1984.

Table 2.3 Sediment Disposal Alternatives

Disposal Alternative	Description
Ocean Disposal (Near Shore or Offshore)	Dispose of Category I material or Category II material with capping in area of low currents.
Subaqueous Pit Containment Facility	Place Category II and III materials in Harbor bottom depression and cap with sand.
Harbor and Ocean Island Containment	Construct enclosed dike and fill with Category II and III sediments.
Upland Disposal	Construct enclosed dike on upland area, line with impermeable material, and fill with Category II and III sediments.
Pennsylvania Mines	Dispose of all (?) categories in abandoned coal mines. After remediating, solidifying, Category II and III sediments, use to remediate acid mine drainage.
Beneficial Use	Use Category I material or decontaminated Category II and III material as a resource (beach nourishment, sand mining, artificial soil, construction aggregate, etc.)

assuming transport of less than 30 miles and use of existing pits with no special management or monitoring measures. A number of pit areas have been investigated in some detail, including the Large East Bank Pit located in the Lower Bay and the 14,000,000 cy Newark Bay pit. Although economically attractive, the use of such pits for toxic sediment disposal has raised issues of long-term stability. The Harbor is an estuary and is subject to both riverine currents and tidal action. Although capped, the stability of the cap in the long term cannot be guaranteed, and toxins may eventually be uncovered and remobilized.

Island containment involves the construction of diked areas or breakwaters of various designs in open water into which dredged material is placed, ultimately creating a new island or peninsula. Typical construction is limited to about 20 foot water depths to minimize construction costs. A 500 acre area is capable of providing disposal capacity for 30 to 150 million cubic yards of sediment, with cost estimates ranging from \$3 to \$20/cy. Concern about the ecological impacts (e.g., erosion, flooding, leaching) of such structures in the Lower Bay complex has been significant.

Upland disposal would typically involve construction of a landfill, with appropriate liners, stormwater collection systems, and possibly a water treatment facility to provide safeguards against runoff. Dioxins are less biologically available and more easily controlled in upland disposal than they are in a marine environment. Transportation and operation are significantly more expensive upland, however, than they are in uncontained marine disposal. There is also

limited space available in the highly populated New York/New Jersey area for construction of large landfill facilities.

The use of stabilized category II and III sediment to remediate and close abandoned coal mines in Pennsylvania is being initiated. It appears that the sediment or sediment plus a basis stabilizer can neutralize acid mine drainage and fill the mines. If this meets environmental criteria, the mines could serve as an almost infinite repository for sediment.

Beneficial use of Harbor sediment offers the potential to not only safely dispose of the material, but also partially or completely defray the cost of dredging. If the sediment can be adequately decontaminated and/or stabilized, applications include:

- beach nourishment and restoration,
- creation of fish and wildlife habitat,
- construction of roads, buildings, and flood control features,
- substitution of sediment for other material which would have to be purchased such as landfill day cover),
- creation of artificial soil, and
- production of other more novel construction materials such as the glass product described in the current report.

Beneficial use of Category I material is relatively straightforward, but is limited by the relatively small quantity of this sediment available. Use of Category II or III sediment requires some form of decontamination, with either separation, destruction, or immobilization of the toxic components as well as dewatering.

#### **2.1.4 Requirements for Sediment Decontamination Technologies**

The sediment disposal problem is complex from the technological, economic, regulatory, and sociopolitical points of view. Solutions are being sought to economically decontaminate and/or beneficially reuse between 500,000 and 2,000,000 cy/year of dredged sediments that are deemed unqualified for ocean disposal. The sediments are generally non-RCRA material (i.e., they do not fail TCLP tests and are not expected to leach harmful levels of metal or organics under RCRA criteria). The sediments are also not TSCA materials, in that they contain only about 1 ppm total polychlorinated biphenyls (PCB's) and ppt levels of dioxins.

Contaminant concentrations that will cause measurable biological effects in a marine environment are not known. Furthermore, the synergistic effects of small quantities of various contaminants on the marine environment are also uncertain. Contaminants not included under RCRA or TSCA (such as petroleum) may adversely impact biological viability without resulting in a formal classification as Hazardous Waste. Decontamination requirements for ocean dumping are, therefore, only determinable via biological testing.

To be successful as a beneficial reuse strategy, any technological solution must therefore:

- be inherently low cost, due to the very large volumes of material to be treated.
- produce a material for which substantial demand exists close to the Harbor area (to minimize transportation and distribution costs), and for which a significant market value exists.
- yield a product which meets all criteria for safe usage by industry or the general public with little or no subsequent environmental controls.
- produce little or no secondary waste streams (solid, liquid, or gas) which would require treatment.
- be sufficiently mature to allow full-scale deployment in the immediate future, and
- be acceptable to the general public.

Complicating the ability to determine decontamination process effectiveness is the unknown effect of the cleanup processes themselves on the sediment's marine impact. For example, the effect of removal of all organics from the sediments on biological activity is not known. Furthermore, physical changes in the sediment properties may also impact marine biological systems. For example, changes in sediment size will effect gas permeability and, possibly, upset the ecosystem. These issues will be important in evaluating the viability of options for reusing the sediment versus preparing the sediment for ocean disposal.

An integrated solution is being sought to the problem of economically decontaminating approximately 500,000 cy/year of dredged sediments that are deemed unqualified for ocean disposal. Preferred solutions are those decontamination processes that can produce useful, environmentally benign materials from the Harbor sediments, rather than only decontaminating sediments to allow ocean disposal.

## **2.2 THE WESTINGHOUSE TECHNICAL SOLUTION**

The Westinghouse Science & Technology Center (WSTC) is developing an integrated plasma processing system for Harbor sediment decontamination that will be designed to:

- Provide an economically feasible solution to the Harbor sediment decontamination problem.
- Convert the sediment waste into a useful material for the Harbor Area (e.g., construction aggregate, roofing granules, or glass fiber products such as rock wool insulation).

- Eliminate the need for Harbor disposal or containment of any dredged waste that the system processes.
- Operate using proven technology that produces no negative environmental impact on the Harbor area.
- Process all existing contaminants in the Harbor sediments.
- Integrate operations of dredging, sediment pretreatment, decontamination, and production of materials for local use.
- Produce no waste streams that transfer the contamination problem to another source.

Developing an integrated process for decontaminating harbor sediments is a straightforward extension of Westinghouse experience in the areas of resource recovery and hazardous and radioactive waste processing. The solution chosen is an integrated sediment vitrification system using a Plasma Melter. Plasma Melter technology has been tested successfully on a number of occasions by Westinghouse for resource recovery and the treatment of hazardous and radioactive waste materials. In a multi-year test programs, the Plasma Melter was used to demonstrate vitrification of materials simulating the contents of a PCB-contaminated landfill. Success was demonstrated on feedstocks ranging from wood and construction debris to wet clay, in all cases producing a stable vitreous (glassy) product which passed EPA's toxic characteristic leaching procedures (TCLP) as a non-hazardous material.

Westinghouse also has substantial experience in the arenas of soil washing, thermal desorption, and other decontamination technologies. Experience ranges from the operation of a fully permitted (TSCA, RCRA, and NRC) Environmental Laboratory that provides treatability testing, process development research, and process field support, through the successful implementation of commercial soil washing and thermal desorption system operating at 10 to 20 ton/hr rates.

Westinghouse supplemented its experience background by subcontracting the sediment pretreatment system pilot tests to Severson Environmental, Inc. Severson has extensive experience in commercial dewatering of sediments and petroleum sludges. They have successfully dewatered petroleum sludges that contain 20 to 30% oil, producing a cake with 60 to 70% solids using plate and frame filter presses.

### **2.2.1 Phase I Program Highlights**

The Phase I Program — Technology Evaluation and Bench-Scale Testing successfully achieved its objectives:

- The Newtown Creek Harbor sediments were successfully characterized in terms of mineral composition, moisture content, organic content, and sulfur content, allowing development of a process to decontaminate the sediment

and product formulations to convert the sediment into useful glass materials.

- A range of product compositions was defined based on the sediment analyses whereby readily processable glass may be economically produced from the sediment which (1) uses only low cost glassforming fluxes and high sediment loading, and (2) will be sufficiently flexible to permit decontamination of sediments having a wide range of compositions.
- Bench-scale melt tests yielded in excess of eleven kilograms of vitrified glass product from Harbor sediment, having good homogeneity, low leachability, and good processing characteristics for a variety of potential commercial products.

### **2.2.2 Phase II Pilot-Scale Test**

Phase II — Pilot-Scale Testing processed 17.5 cubic yards of feed sediment in a pilot unit that features a commercial-scale plasma torch and a reactor that has been demonstrated to produce up to 9 tons/day of glass. The Phase II Pilot Program objectives were to:

- Confirm the plasma reactor design, operating conditions, and performance such as organics destruction and the fraction of metals reporting to the glass.
- Confirm the pretreatment system design and the filtrate water stream's composition.
- Establish the off-gas compositions, providing the basis for commercial offgas treatment system design.
- Generate glass product of the target characteristics, allowing an assessment of glass product manufacturing options.
- Confirm the environmental acceptability of process output streams.

Using the Phase II Pilot Test data, we will design an integrated Plasma Vitrification Treatment Train including a pretreatment system involving simple size segregation, desalinating, and dewatering, preprocessing steps that improve the integrated system economics and simplify the vitrification process.

### 3. CONCLUSIONS AND RECOMMENDATIONS

The Phase II Plasma Pilot Tests processed 17.5 tons of dredged sediment material received from Newton Creek. All dredged material was pretreated to remove oversized material and remove water from the sediment. The dewatered sediment was mixed with glass fluxes and fed at a rate of 1200 lb /hour (i.e., equivalent to 1600 lb of dredged material per hour) into the plasma melter to produce glass. Samples of all process streams were taken and shipped to Brookhaven National Laboratories (BNL). BNL was responsible for contracting analysis of all sample streams. The analyses performed were used to complete a material balance on the system, evaluate the decontamination performance of the process, and refine the full-scale plant design and cost estimate.

The Phase II pilot Test Program successfully achieved its objectives.

#### **Objective 1: Confirm the Plasma Reactor Design and Operating Conditions**

Westinghouse successfully processed 17.5 tons of Newtown Creek sediment to demonstrate the crucial technology components of the integrated plasma vitrification treatment train. The sediment was screened, rinsed, dewatered, mixed with fluxes, and fed to a plasma melter. The plasma melter destroyed the sediment's organics and produced a molten glass. The molten glass was quenched to produce glass aggregate.

#### **Objective 2: Demonstrate Performance of the Plasma Reactor**

Key performance parameters of the plasma reactor were successfully demonstrated in the Phase II Pilot Tests.

- The plasma process achieved essentially complete, 99.9999%, destruction of hazardous organics fed to the reactor.
- Product and sidestream analysis demonstrate hazardous metal incorporation into the product glass; 80% of the hazardous metals were retained in the product glass, while leaching tests on the glass product show that the glass passes TCLP leach criteria by orders of magnitude.
- The glass produced in the pilot tests is environmentally safe, and glass manufacturers indicate that it has potential to be formulated into high-value commercial glass products.
- The energy required to melt the sediment glass was demonstrated to be 1.3 MWhr/ton of dredged sediment, lower than our assumed target.

**Objective 3: Confirm the Pretreatment System Design**

Sediment was successfully dewatered to 58% solids. The filtrate water's composition was determined to meet discharge criteria.

**Objective 4: Establish Offgas Compositions**

Melter offgases were directly sampled before any gas cleaning occurred. Offgas SO<sub>x</sub>, NO<sub>x</sub>, particulate, organic, and metal compositions, together with emission requirements, provide a data base for designing a commercial gas cleaning system.

**Objective 5: Generate Glass Product of the Target Characteristics**

Test 3 produced about 3500 lb of quenched glass product. The glass produced has allowed an assessment of some glass product options.

**Objective 6: Confirm the Environmental Acceptability of Output Streams**

Process output streams were characterized by analytical contractors selected by BNL. The Westinghouse process minimizes waste streams. Glass product will have a volume of only 16% of the sediment feed volume. The total solid waste remaining after processing is less than 3% of the input sediment weight. The only contaminated waste, stabilized metals removed from the offgases, amounts to 0.1% of the input sediment weight. Clean filtrate water and scrubber bleed water will be discharged. Clean offgases will be discharged to the stack.

The Phase II Pilot Test provides a basis to design an integrated Plasma Vitrification Treatment Train, including a pretreatment system involving simple size segregation, desalinating, and dewatering steps that improve the integrated system economics and simplify the vitrification process. Although the preliminary design phase is in progress, we have provided an interim update on the design and cost of a commercial plant in this Phase II Test Report. Cost assessments indicate that the plant is economical; it effectively decontaminates sediment at operating costs of \$57 to 84/ton. Estimates of capital-based costs and glass manufacturing costs increase the total plant costs to \$100 to 126/ton. The process has the potential to offset the costs, or generate income, if the product glass can be used to make commercially viable products. The value required of a glass product that will allow the plant to break-even, operate with no expenses, is \$130 to 330/ton.

Several high value glass products have been identified as promising candidates to manufacture using the sediment glass as a raw material. The pilot sediment glass has chemical and physical properties that are compatible with the manufacture of fiber glass products and glass tile, both products have large market needs and commercial values as high as \$500/ton.

The successful demonstration and excellent decontamination performance achieved in the Phase II Pilot Tests encourage the pursuit of a demonstration for the Westinghouse Plasma Sediment Decontamination Process. A preliminary

design is needed to fully develop the sediment decontamination process and determine the economics of a commercial plant. A key to the plant's economics will be the ability to produce a useful, high value glass product from the molten glass melt. We, therefore, recommend that manufacturing options for high value glass product be verified on samples of prototypical pilot glass.

## 4. PILOT TEST FACILITY

The Phase II Pilot Scale Tests were performed at the Westinghouse Plasma Center in Madison, Pennsylvania, roughly 30 miles east of Pittsburgh. This facility includes the Plasma Melter Pilot Plant, a multi-ton-per-day facility which is operated by the Westinghouse Science and Technology Center. This facility has been designed to be highly flexible and heavily instrumented, and is used for demonstration testing and process development in a wide range of plasma melting and processing applications.

The overall vitrification pilot-scale process schematic is shown in Figure 4.1. Five sampling locations were used to collect samples during the pilot tests; they are indicated in Figure 4.1 with boxes, locations V1 to V5. Pretreated feed is injected into the melter tuyere. A commercial sediment pretreatment system was supplied by Severson and operated at the Plasma Center. The pretreatment system is described in Section 5.

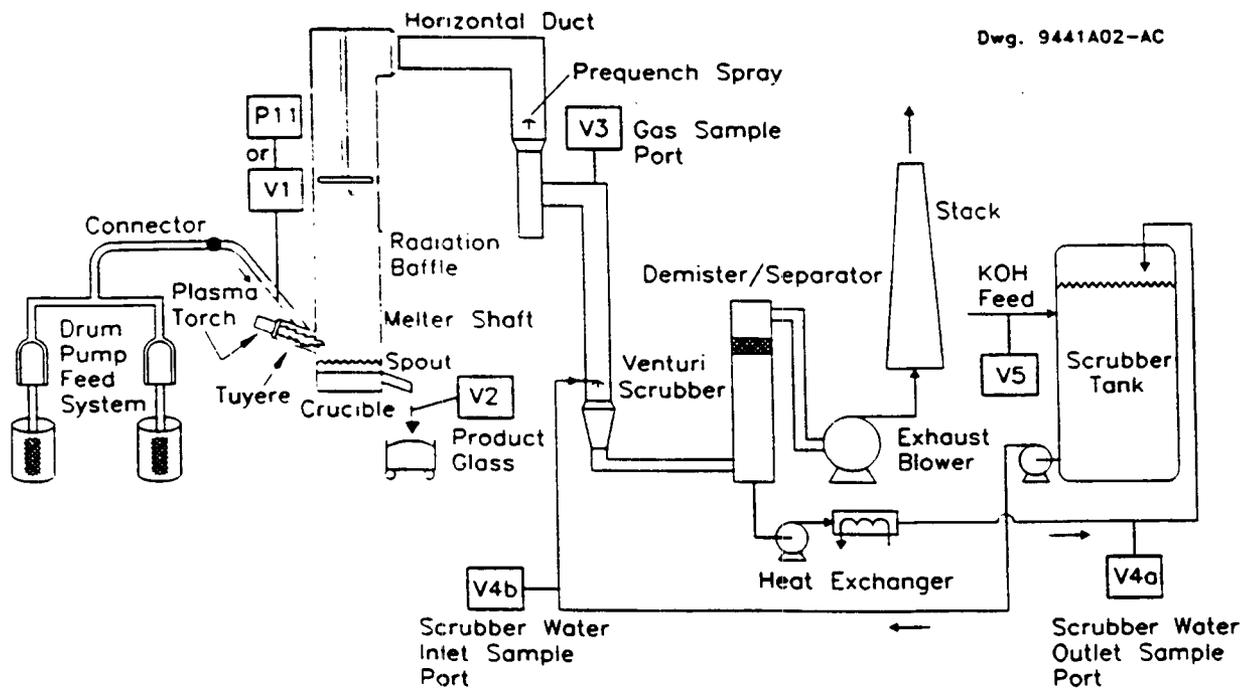


Figure 4.1 The Westinghouse Pilot-Scale Plasma Melter

The plasma facility consists of a Plasma Melter including a Westinghouse Marc-11 plasma torch thermal source capable of 2.3 MW output, several feed supply systems, a glass product collection system, a scrubber system for separating and collecting aerosols and volatiles, and a state-of-the-art process control and data acquisition system.

To minimize the possibility of shutdown due to the unlikely event of equipment failure, primary and backup plasma torches and power supplies are available to supply thermal energy. The Plasma Center control room facilities and data acquisition system are dedicated to pilot testing. In addition, the Plasma Center provides a team of engineers and technicians intimately familiar with the operation of the melter, and skilled in handling a wide range of materials both hazardous and nonhazardous. The site is both secure and fully permitted.

#### **4.1 THROUGHPUT**

The plasma melter has produced up to 8 metric ton/day of a vitrified glass product. Typical injection rates are between 1 and 2 gallons per minute processing feed slurries. The Phase II Pilot Test average feed rate was 1200 lb/hour of sediment plus glass fluxes. This is equivalent to processing 1600 lb/hour of dredged material.

#### **4.2 MATERIALS FEEDING SYSTEM**

The feedstock supply capabilities for the Plasma Processing Facility consist of dry feed systems, liquid/slurry feed systems, and a powdered flux feed system. The pumping system selected for the mixed sediment and glass fluxes was two Graco 50:1 King pumps, which pumped directly from 55-gallon drums and were capable of providing up to 4 gallons/minute of feed at pressures as high as 4500 psig. These drum pumps could handle materials with viscosities of 100,000 to 2,000,000 cp. Sediment mixes were pumped through a 1-inch injection port into the melting tuyere.

#### **4.3 PLASMA MELTER DESIGN**

The heart of the treatment process is the plasma-fired vitrification reactor, shown in Figure 4.2. The pilot-scale Plasma Melter is a vertical shaft design, refractory-lined to provide a 35-inch inner diameter. The shaft is lined with a high-alumina refractory material which has shown good resistance to vitreous slag materials in past melter testing. A refractory-lined crucible mounts to the bottom of the vertical shaft with a bolted flange for easy assembly and disassembly. A tap hole at the bottom of the crucible is integrated with a heated spout assembly to provide a flow path for molten, vitrified waste glass. During test operations the vitrified product is collected in steel mold boxes, supported by sand-lined steel containers mounted on rails for easy removal from the Plasma Melter.

In production operations, the molten product would be (1) directly quenched into water to shatter the glassy slag into aggregate, (2) granulated in a controlled manner to produce uniform roofing granules, or (3) centrifugally thrown into glass fibers for rock wool fabrication.

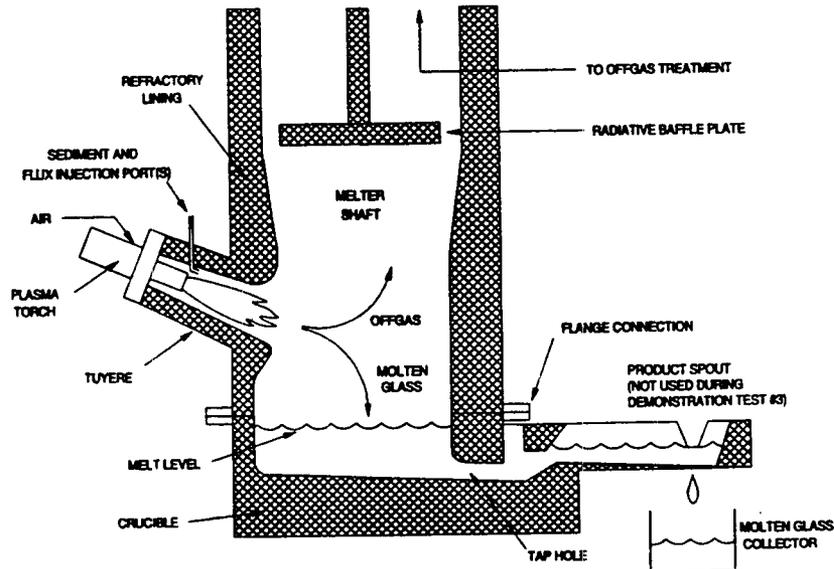


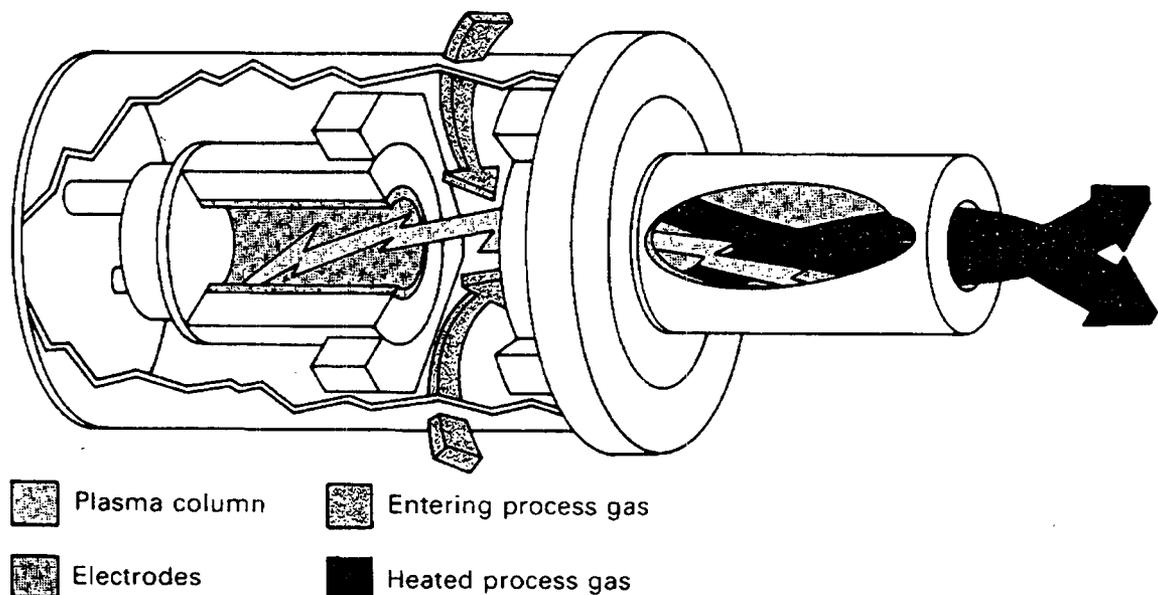
Figure 4.2 The Plasma Melter Crucible Design

The Plasma Melter is designed for either solid or liquid feed. The dewatered sediment will be combined with fluxes (lime and soda ash) and sufficient water to provide a pumpable dense slurry (about 50% weight solids), and the resulting mixture injected directly into the vitrification tuyeres through injection nozzles. The vigorous tuyere air circulation and rapid flashing of the sediment moisture content cause rapid mixing of the waste with the extremely hot (5000°C) plume generated by the plasma torch, producing a mixing temperature well in excess of 2200°C. Decomposition of even relatively refractory organic carbon compounds such as PCBs and dioxin is nearly instantaneous.

#### 4.4 PLASMA TORCH DESIGN

Process heat is supplied by a commercially available Westinghouse non-transferred arc Plasma Torch, mounted to one side of the crucible zone in an entry duct known as a tuyere. A production scale Westinghouse Marc-11 Plasma Torch supplies the thermal energy to the Plasma Melter. The Westinghouse non-transferred arc plasma torch is a rugged and commercially available technology. The torch is rated at 2300 kW input electrical power, with an overall torch-and-tuyere electrical-to-thermal efficiency between 80 and 90%. The torch design uses a

pair of cylindrical, water-cooled electrodes to generate a DC arc, which is rotated by an electric field. Process gas is injected through the cylindrical electrode gap at typical flowrates of 100 to 150 scfm. The high velocity of the gas carries the arc into the throat of the torch, and heats the working gas to extremely high temperatures. Field coils rotate the electrically conductive plasma at high rotational velocities, such that the point of contact of the arc with the downstream electrode is constantly moving. This feature minimizes ablation of the electrode, and leads to electrode lifetimes which are the best in the industry. The superheated process gas is mixed with additional gas at the torch nozzle; this shroud gas flow blankets the superheated plasma plume and extends the life of the tuyere refractory.



**Figure 4.3 The Westinghouse Marc-11 Plasma Torch**

Because of the simplicity of its construction, maintenance on the Westinghouse plasma torch is simple and requires little time. In typical industrial operations, the plasma torch is connected to the melter by simple flange connections, with all of the required utilities connected through the mounting flange. Disconnection of four bolts, two electrical connectors, and several quick-connect fittings supplying air and cooling water allows the torch to be changed out in less than fifteen minutes.

The electrodes within the torch eventually require replacement due to slow ablation. Typical electrode lifetimes are 750 to 1500 hours on the downstream electrode, and 1000 to 3000 hours on the upstream electrode. Replacement of the electrodes, however, is a quick and inexpensive operation. In a commercial melter with several torches, the operation of melter need not be interrupted for torch electrode replacement. A single torch is disconnected from the tuyere and swapped

out for a spare torch, a process requiring only 15 minutes time. Full electrode rebuilding can be accomplished by one individual in less than one hour.

#### 4.5 OFFGAS-HANDLING CAPABILITIES

Offgas handling in the pilot test is shown in Figure 4.4. The Pilot Plant uses a venturi scrubber, and eliminates the filtration train downstream of the scrubbing system. No separate sulfur removal system is provided, with  $\text{SO}_2$  removal occurring in the scrubber. The two-stage quench and dry-sorption system is designed to cool the overall gas stream, remove sulfur oxides, and condense volatile salts (primarily  $\text{NaCl}$ ) which may be entrained in the melter offgases. The high-efficiency scrubber then removes condensed particulates from the exhaust stream. The separator/demister removes additional solid particulates and aerosols and thoroughly scrubs the exhaust stream, capturing water soluble offgas products and sending them to a holding tank for recycle to the scrubber. Environmentally acceptable  $\text{N}_2/\text{O}_2/\text{CO}_2$  offgases are ejected by the blower through an exhaust stack.

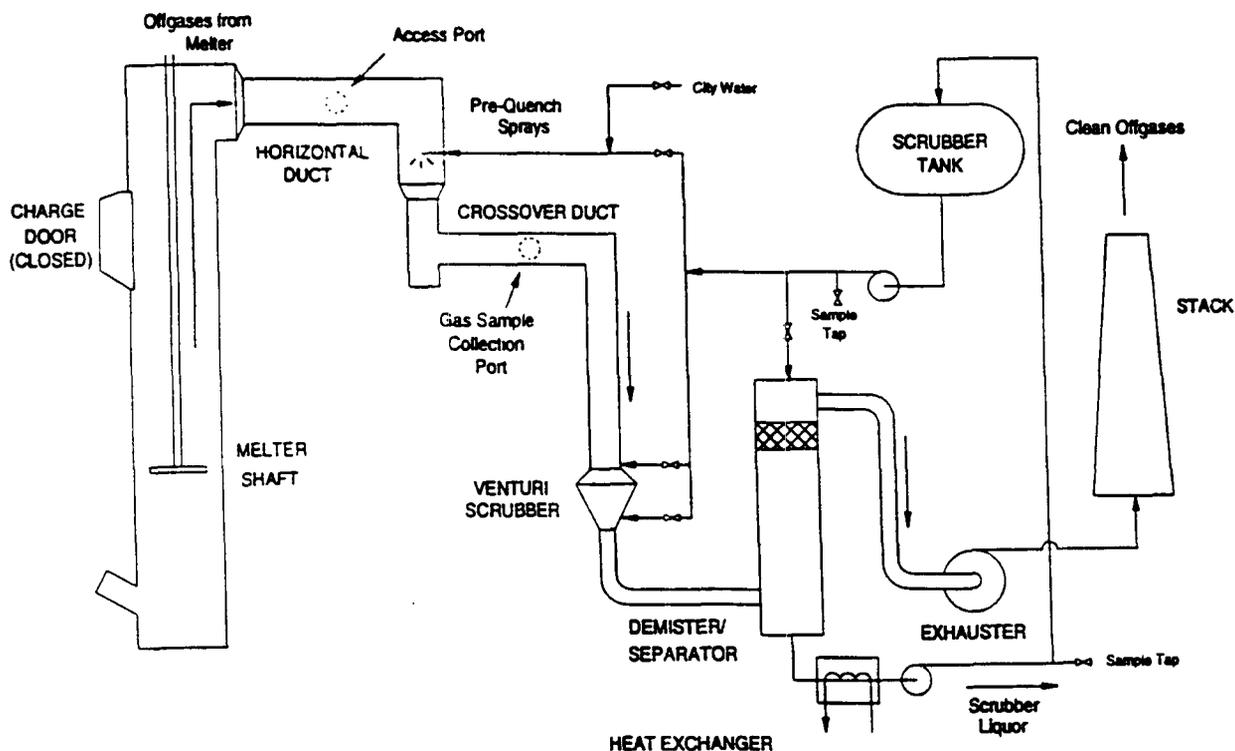


Figure 4.4 The Pilot Plant Offgas Handling System

#### 4.6 SAMPLING, INSTRUMENTATION, AND TEST-MONITORING CAPABILITIES

The Plasma Melter facility has a variety of sampling locations for removing feed, product, and offgas samples to aid in process monitoring and control and for performing the crucial overall mass balance analysis. Pilot Plant sampling locations are shown in Figure 4.1. A sample of feed material, sample location V1, was taken from each drum. Glass aggregate product, sample location V2, was stored in containers as it was produced. The melter offgases were sampled directly from the offgas duct, sample location V3. Note that no gas cleaning was performed prior to offgas sampling so the sampled offgases contain any and all metals, particulate, and organics exiting the plasma melter. The scrubber water was sampled at least every hour from two locations, the outlet (location V4a) and the inlet (location V4b). BNL was supplied initial and final scrubber water samples; the final sample contains the metals accumulated from the entire test. One final sample location, V5, provided a sample of potassium hydroxide that was periodically added to the scrubber water for neutralization.

The Plasma Melter System is equipped with on-line gas analyzers for obtaining off-gas concentrations of nitrogen oxides (NO/NO<sub>x</sub>), oxygen (O<sub>2</sub>), and hydrogen (H<sub>2</sub>). The NO/NO<sub>x</sub> analyzer is a multi-range Beckman, Model 951 H, with sensitivity of  $\pm 1$  ppm and a maximum of 10,000 ppm. The O<sub>2</sub> analyzer is a multi-range Beckman instrument with sensitivity of  $\pm 0.5\%$  by volume and a maximum of 25% by volume. The H<sub>2</sub> analyzer is a Thermatron instrument with a sensitivity of  $\pm 0.1\%$  by volume and a maximum of 10% by volume. The outputs from the analytical instruments are constantly monitored and recorded by the control room data acquisition system. In addition to the on-line instrumentation monitors, bomb samples of offgas were obtained at least every hour for analysis of other gases of interest (such as sulfur dioxide). These bomb samples were taken upstream of the V3 gas sampling port, suctioned directly from the melter area.

#### 4.7 PROCESS CONTROL EQUIPMENT

Process control equipment includes a process logic controller for monitoring critical process variables and alarming or activating system shut-down when alarm set points have been exceeded. The sediment flowrate, torch input power, and process gas flowrate are operator controlled to obtain the desired product production rate, desired product composition, and Plasma Melter operating conditions.

The pilot-scale Plasma Melter is highly instrumented with temperature, pressure, and flow measurement devices to completely characterize the heat and material balances around the melter. Figure 4.5 illustrates the process instrumentation on the pilot unit. The instrumentation includes strategically located thermocouples, pressure transducers, flowmeters, power meters, and voltmeters to control, monitor, and record torch power, feed streams, product stream, and offgas. Critical data are recorded on the computer data acquisition systems and chart recorders allowing real-time control of process parameters such

as torch input power, feed flow, process gas flow, glass flux input rate, product formation rate, product stream temperature, and offgas temperature, flow rate, and composition. Data collection and process control are further enhanced by operator-maintained data reduction graphs and charts. A Hewlett Packard Model 3054A Automatic Data Acquisition/Control System interfaces with several personal computers for data archiving and data reduction.

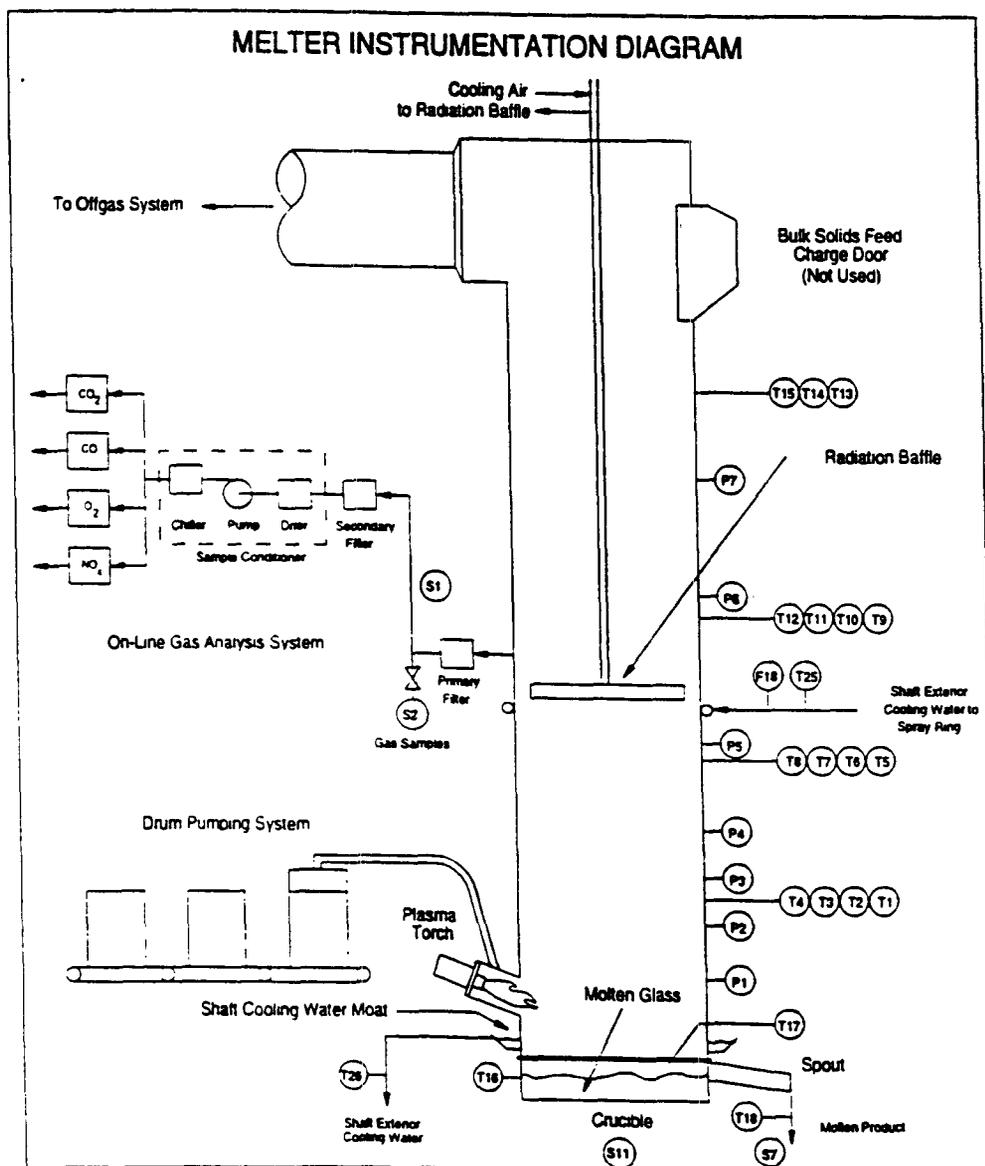


Figure 4.5 Pilot Unit Instrumentation

## 5. SEDIMENT PRETREATMENT OPERATIONS

The following section describes the Phase II pilot pretreatment operations performed on 17.5 cy of Newtown Creek sediment. Pretreatment was performed for the purposes of size classification, salt removal, and dewatering. These operations were done in preparation for plasma vitrification of the sediment. Characterization of the feed is also presented because the feed characterization formed the design basis for the pretreatment train selected.

### 5.1 FEED CHARACTERIZATION

Establishment of the pretreatment system parameters first required analysis of the sediment to establish (1) the fundamental mineralogy and permit optimization of the glass recipe, (2) the salt content to determine the wash water volumes required, (3) the moisture and solids content, (4) the organic content of the dry solids to provide the mineral content basis, and (5) RCRA metals and contaminant analysis for determining starting points for percent destruction or retention.

Two rollofs of Newtown Creek sediment (Figure 5.1) were received in July of



Figure 5.1 Newtown Creek Sediment Received for Phase II Tests

1996, and samples of each were sent to Corning Engineering Services Laboratory (CELS) for analysis of metals, chloride, sulfur, carbon, and moisture, as well as semiquantitative scans for RCRA metals. Results are presented Figure 5.2 and summarized in Table 5.1; Phase II metals and moisture analysis are presented along with renormalized contaminant data from Phase I. Little difference is seen between the two rollofs (labeled A and B), with the sole exception of the CaO content; CELS noted in their analysis that the Rolloff A sample was inhomogeneous, and contained several white specks which may have been limestone or some other calcium compound. Both samples were 38 to 39% solids (61 to 62% moisture), and contained about 1% NaCl, consistent with Phase I analysis and the anticipated salt content of estuarine water.

The appearance of the material was also similar to that of the Phase I sediment. The material appeared black and oily with an odor of creosote, drying to a fine gray claylike powder. The as-received rollofs contained not only sediment but a considerable quantity of debris (e.g., sticks, bits of trash, leaves). In addition, a large quantity of dredging operation waste was also dumped into the rollofs, including large sheets of plastic, gloves, booties, cardboard boxes and tubes, paper and plastic bags, fast food containers, insulation board, and plastic suits. These all had to be dug out of the sediment before processing could take place; they filled several 55-gallon drums.

Phase I testing had identified a basic glassforming recipe using only soda ash ( $\text{Na}_2\text{CO}_3$ ) and lime (CaO) as fluxing species at a mass ratio of 1:2. This formulation minimizes total chemical costs to the process, since lime is considerably cheaper than soda ash. The target loading  $\lambda$  (defined as kg of sediment metal oxide per kg final glass) established in Phase I crucible melts was 83%, producing a glass composition with a 100-poise melting point of 1420°C. Based on the analyses presented above, 83% loading recipes were formulated for sediment from each of the two rollofs. The final target glass compositions are shown in Table 5.2. Note that the melting temperature of the Phase II glass is somewhat above that of Phase I, primarily due to the higher alumina content. The predicted melt viscosity is shown in Figure 5.3. In vitrification tests (discussed in Section 6), the viscosity of the 83% loading formulation was found to be higher than desirable, so that Rolloff A sediment was processed at a lower loading of 77%, accomplished by adding more fluxes with a slightly higher Na:Ca ratio.

**Phase II Analysis of As-Dredged Newtown Creek Sediment**  
 Mineralogical Analysis by Corning Engineering Laboratory Services, July 24, 1996;  
 RCRA and Organic Contaminants Based on Phase I Analyses

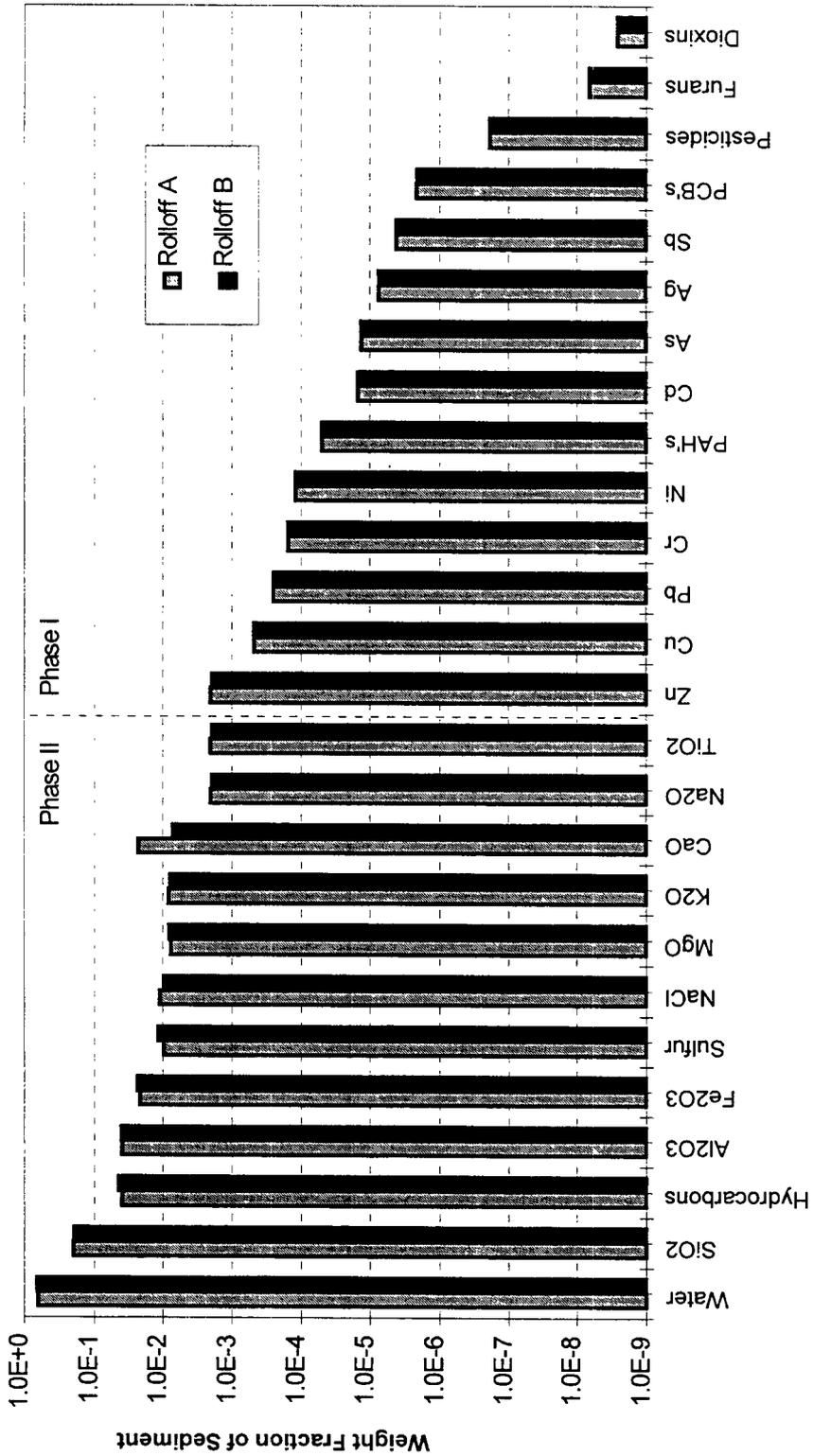


Figure 5.2 Overall Analysis of Newtown Creek Sediment Samples

Table 5.1 Analysis of Phase II Newtown Creek Sediment

Component	Rolloff A	Rolloff B	Phase I
<i>Phase II CELS Sediment Analysis (w/o)</i>			
Water	63.5	64.7	66.1
Hydrocarbons	3.88	4.34	5.76
Sulfur	0.974	1.19	0.60
NaCl	1.11	0.974	1.16
SiO <sub>2</sub>	19.8	19.3	13.02
Al <sub>2</sub> O <sub>3</sub>	3.88	4.03	3.45
Fe <sub>2</sub> O <sub>3</sub>	2.20	2.38	2.38
CaO	2.32	0.740	0.65
MgO	0.767	0.818	0.64
Na <sub>2</sub> O	0.203	0.196	0.25
K <sub>2</sub> O	0.832	0.802	0.75
TiO <sub>2</sub>	0.203	0.196	0.27
<i>Based on Phase I CELS Sediment Analyses (ppm)</i>			
Zn	710	705	585
Cu	475	474	397
Pb	250	250	209
Cr	153	153	124
Ni	121	120	101
Cd	15.1	15.0	12.6
As	13.6	13.6	11.3
Ag	7.46	7.45	6.25
Sb	4.18	4.17	3.49
PAH's	49.6	49.5	39.7
PCB's	2.13	2.13	1.78
Chlorinated Pesticides	0.187	0.187	0.157
Furans	0.00657	0.00656	0.00559
Dioxins	0.00261	0.00261	0.00219

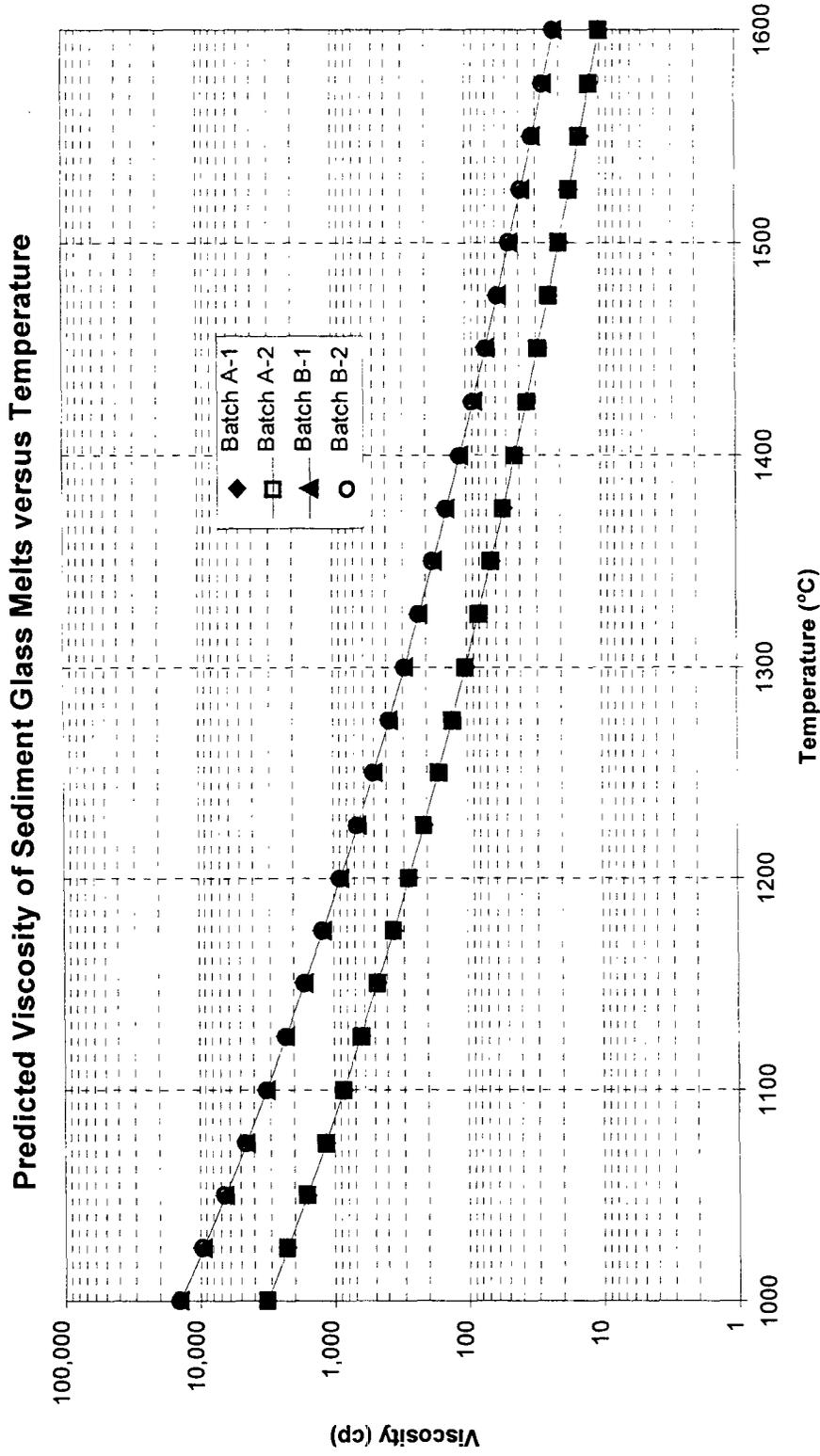


Figure 5.3 Predicted Viscosity of Sediment Glass

Table 5.2 Target Compositions for Glass

Component	Sediment A Glass (w/o at 83% Loading)	Sediment B Glass (w/o at 83% Loading)
SiO <sub>2</sub>	55.7	54.3
Al <sub>2</sub> O <sub>3</sub>	10.9	11.4
CaO	13.4	13.3
Na <sub>2</sub> O	8.3	8.7
Fe <sub>2</sub> O <sub>3</sub>	6.2	6.7
MgO	2.2	2.3
K <sub>2</sub> O	2.3	2.3
TiO <sub>2</sub>	0.9	0.9
CuO/ZnO	0.2	0.2
Total	100.0	100.0

## 5.2 PRETREATMENT FLOWSHEET

Based on the above data, a pretreatment strategy was devised as shown in Figure 5.4. Samples of all input and output streams labeled in Figure 5.4 were taken during the pretreatment operations and supplied to BNL. The sediment was removed from the rolloffs, prescreened to remove large debris and particles greater than 1 mm in size, rinsed to remove salt, pressed to a solids content in excess of 50%, and then blended with glass fluxes in preparation for feeding into the plasma vitrification system. The following sections describe each of these pilot operations performed on the Newtown Creek sediment provided to Westinghouse for testing.

### 5.2.1 Sediment Mobilization

Prior to treatment, the volume of sediment in each rolloff was established by depth sounding at ten points along each side of the dumpster. An inventory of 8.94 and 8.54 cy was logged in Rolloffs A and B, respectively, for a total of 17.48 cy (3,528 gallons). Density measurements of 1.28 and 1.24 gm/cm<sup>3</sup> were made for the two rolloffs, giving the a total sediment mass of 16,711 kg.

The first step in pretreatment was mobilization of the sediment. This process involved sluicing the sediment out of the rolloffs with addition of water, using a large Wilden M15 pneumatically-driven double diaphragm pump and a 2.5" firehose to remove material from the containers. As sluicing proceeded, large debris (plastic sheet, paper cups, large sticks, etc.) were removed by hand. In plant operation, the dredgings would first be screened through a grizzly screen to remove such debris. In pilot operations, a 1" screen was placed at the inlet of the firehose to prevent ingestion of material which would clog the pump. The sediment was found to have

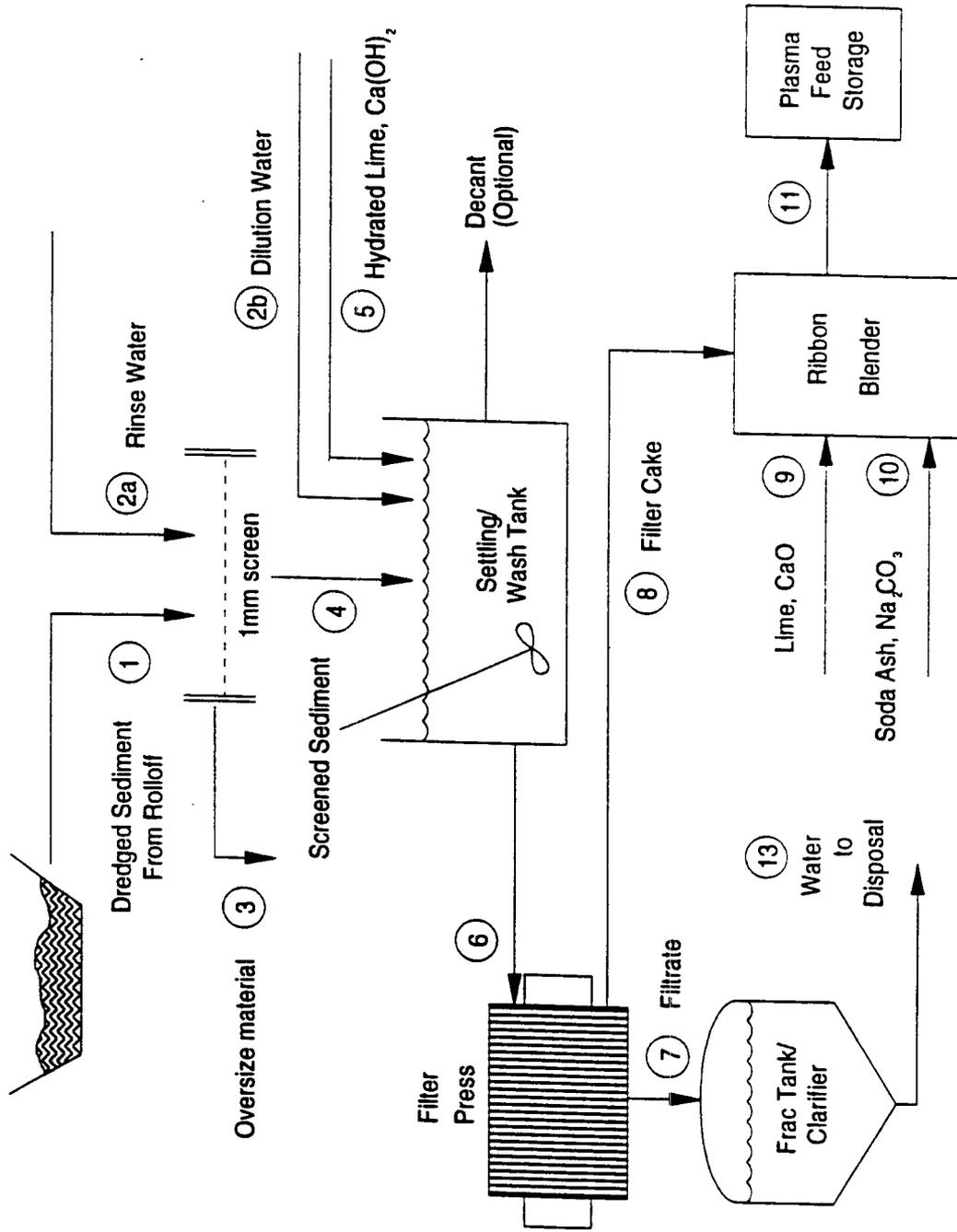


Figure 5.4 Sediment Pretreatment Flowsheet

sufficient trash content (i.e., primarily leaves) that the Wilden pump was susceptible to frequent clogging, and was replaced by a diesel-driven Godwin CD-150 trash pump. The Godwin pump readily handled the material, with periodic cleaning of the inlet screen.

The pumping process was capable of removing all but 1" of sediment slurry from the bottoms of the rolloffs, or approximately 375 gallons of diluted sediment (about 10% solids) in each. These heels were rinsed out later with additional water, and ultimately pressed into a fifth filtration cycle along with material gleaned from the various tanks, drums, and transfer lines.

### 5.2.2 Screening and Mixing

The partially screened material was then pumped onto a 4 ft × 4 ft Brandt vibratory multistage screen shown in Figure 5.5. The screen size was set to pass material under 1 mm in size. The oversize material ("cuttings") vibrated off the screen, and fell into a receiving area (i.e., several 55-gallon drums inside a containment dike). This material was then collected, combined with the larger debris material removed by hand (not counting the trash thrown in on top of the sediment by dredging operators), and weighed.

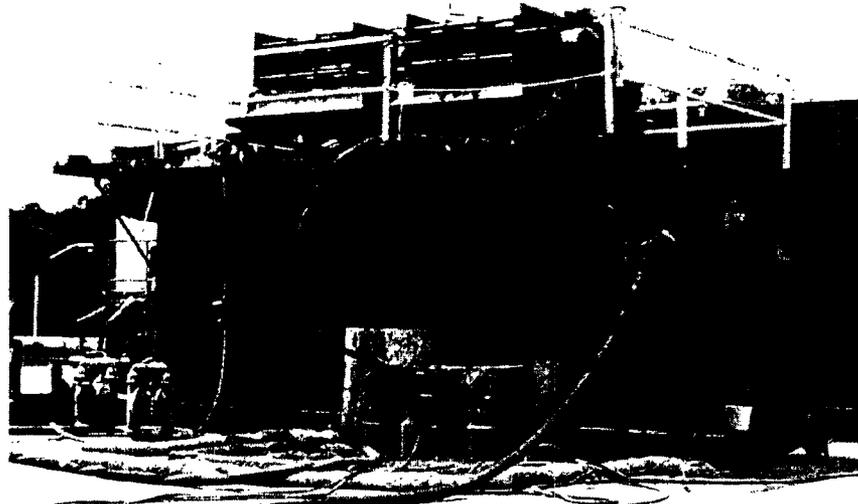


Figure 5.5 Sediment Screening Operation

Undersize material passing with the rinse water through the screen dropped into a large (8 ft × 21 ft × 8 ft depth) rectangular steel mixing tank having an internal volume of approximately 10,000 gallons. The mixing tank was equipped with a 30" four-bladed paddle agitator set several inches from the bottom. The volumetric inventory in the tank was monitored by liquid depth, based on precalibration ("strapping") of the tank at 105 gallons/inch. Water addition due to sluicing and rinsing was back-calculated by difference from the tank volume and the original rolloff volume, including the volume of oversize material. At this point, the

mixture was computed to contain roughly 12% solids. Each rolloff produced a mixture volume of between 5,000 and 6,500 gallons of diluted sediment slurry.

### 5.2.3 Hydrated Lime Addition

Once the sediment had been transferred to the mixing tank, approximately 0.1 lb/gallon of  $\text{Ca(OH)}_2$  (hydrated lime) was added to the mixture to aid in agglomeration. Because of the very fine particle size of the sediment, filtration was expected to be difficult. Bench-scale dewatering treatability testing at Severson's Waste Stream Technology Laboratory provided the results shown in Table 5.3. At 10% solids content feed, it was not possible to effectively filter the sediment without addition of an agglomerating agent. However, at either 10% or 20% solids feed, good filter cakes were obtained by addition of between 0.10 and 0.20 lb/gallon of hydrated lime.

**Table 5.3 Agglomeration Additive Treatability Test Results**

Feed Solids Concentration (w/o)	Lime Concentration (lb $\text{Ca(OH)}_2$ /gallon)	Filter Cake Solids Content (w/o)	Filter Cake Density ( $\text{gm/cm}^3$ )
20	0.10	59.57	1.48
20	0.20	57.92	1.47
10	0.15	49.77	1.33
10	0.00	None	None

Addition of calcium hydroxide poses no difficulty to the process, since calcium must be added anyway to achieve the desired glass recipe. However, addition of calcium as  $\text{Ca(OH)}_2$  is less desirable than addition as  $\text{CaO}$  for two reasons:

1. Addition of  $\text{CaO}$  (quicklime) achieves additional dewatering as a result of hydration reactions and temperature elevation.
2. Calcium hydroxide (hydrated lime) must eventually be converted to  $\text{CaO}$  by the plasma vitrification process before incorporation into the glass matrix, requiring some additional electrical energy input as compared to calcium oxide.

Since maximum solids content plasma process feed was desired, the minimum hydrated lime additive (0.10 lb/gallon) was selected, with an anticipated 20% sediment slurry resulting from sluicing and rinsing.

Bench testing at Severson also indicated that lime addition would result in settling of the sediment-water mixture, such that a substantial portion of the water could be removed by decantation (as shown in Figure 5.4). The mixture was allowed to stand for two hours, and then samples were taken at various depths below the surface to determine the settling rate. (The slurry was black and entirely opaque;

the settling interface could not be determined visually). The settling rate was found to be very slow, with roughly 10 hours anticipated to achieve 50% clarification of the mixture. To avoid long delays in processing, the decision was made not to settle and decant, although this remains an attractive low-cost option for plant operation for partial dewatering.

Sevenson bench testing had shown that filter pressing of 12% solids feed should readily achieve a filter cake having in excess of 50% solids, which was satisfactory for plasma system feed. The hydrated lime was increased in later batches to enhance filterability, and the flux CaO addition reduced accordingly to maintain constant calcia in the final glass mixture.

#### 5.2.4 Press Filtration Dewatering

The next step in the process was therefore to pump the sediment mixture to a large Durco Quadra filter press (Figure 5.6) through a 3" line, using the Wilden

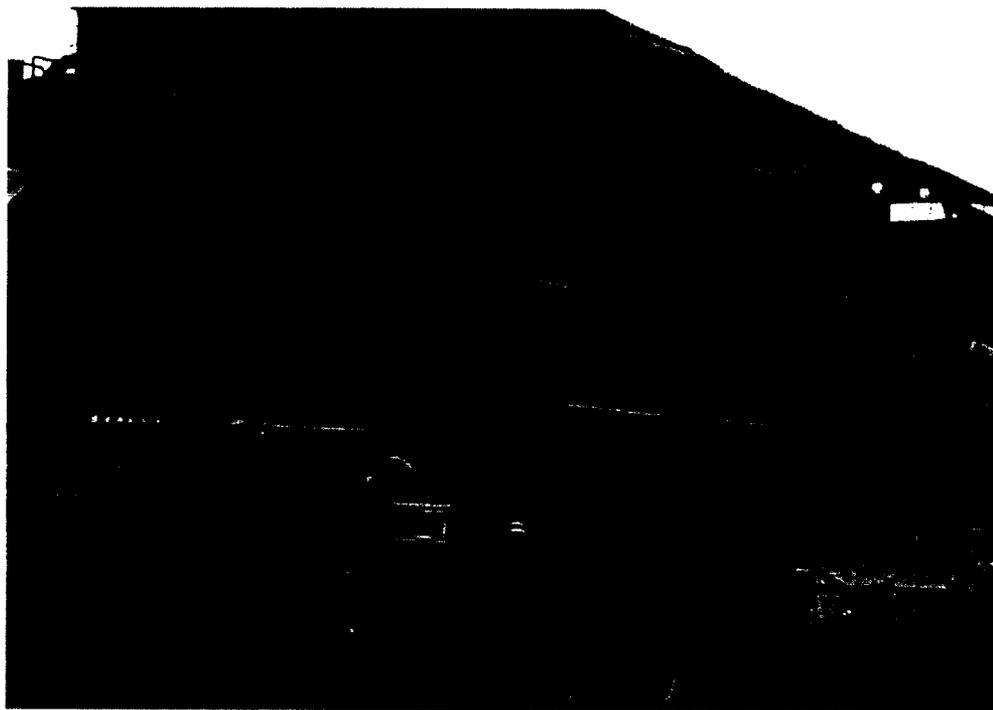


Figure 5.6 Filter Pressing Produced a Dewatered Cake

pump. This device, small by industrial standards, utilized seventy-two 48" x 48" frames, with center feed and alternating corner filtrate takeoffs. The filter typically operated at 125 psig pressure, and had a capacity of 2.74 cy per load ("drop"). The volume of sediment slurry required to complete a press drop depended on the solids loading. Two drops were required to process the sediment from each rolloff, with the first drop of each set typically filtering 3,200 to 4,000 gallons of lower solids content material, and the second drop filtering between 1,200 and 2,000 gallons.

Rolloff B was processed first, followed by Rolloff A. Note the heel of Rolloff B material left in the mixing tank was accounted for in the material balance.

Once the filter was fully loaded, pumping of sediment ceased and air was blown through the cake to remove excess water. The filtrate collected from the pressing operation was pumped to a large portable storage container ("frac tank") for analysis and disposal. The filtrate was essentially free of particulates, but had a slight yellow coloration. Filtrate from the first batch of a given rolloff was considerably darker than filtrate from the second batch. Samples were collected for analysis.

Once the collection of filtrate had ceased, the frames were opened and the cake dropped onto a moving belt and dumped into the bucket of a Bobcat front-end loader. At this point, the sediment had been dewatered to a dense claylike filter cake containing between 51 and 57% solids, in agreement with the dewatering treatability data shown in 5.4. Four batches of filter cake were recovered, designated A-1, A-2, B-1, and B-2; a fifth batch was prepared from the heel remaining in the mixing tank, rolloff heels acquired from cleaning the dumpsters, and various drum heels.

### **5.2.5 Flux Addition and Blending**

From here the filter cake was moved into a large V-shaped 10 ft × 8 ft delumper hopper, equipped with mixing flights (1" rods mounted to a rotating shaft at 60° inclines) and a screw auger for emptying. The glass fluxes were dumped into this hopper, and the mixing system activated to blend the filter cake with the fluxes. As indicated above, CaO and Na<sub>2</sub>CO<sub>3</sub> were added to achieve a sediment metal oxide loading of 83% in the final glass melt. The mixing system did not prove to be optimal, as the mixing flights were not properly designed to blend a sticky material. Hand turning of the charge was required to achieve a uniform mixture. All of the filter cake from Rolloff B was blended with fluxes in two batches. The filter cake from Rolloff A was not blended with fluxes at this time, but rather stored as unblended filter cake. Batches B-2, A-1, and A-2 were stored in closed drums, while batch B-1 was stored in open steel boxes.

It was observed that although the freshly pressed filter cake was soft and easily blended (batch B-1 experience), the material would "set up" upon standing, even though no apparent change in net water content occurred. Filter cake B-2 was loaded into the hopper and fluxes added, but actual blending was not attempted until 24 hours later. The material had set up sufficiently that both the drive chain and the torque coupling on the drive motor fractured under the startup load, necessitating delay and repair. Blending was finally accomplished with significant hand labor three days later.

Several mechanisms have been postulated to explain this phenomenon. As a result of chemical reaction between water and quicklime, some increase in temperature occurred (up to 20°C); the result was a further decrease of 1 to 2% in free moisture content, both due to hydration reaction and steaming. It would be

expected that sediment viscosity would increase with decreasing moisture content. Batch B-2 material was never premixed with the fluxes prior to the mixer failure, however. It was still felt to be possible that simple drying had occurred over the 24 hour delay time.

Tests were therefore carried out at Westinghouse to determine the viscosity of the sediment as a function of moisture content. The results of these tests on batch A-1 filter cake are shown in Figure 5.7. It is seen that increase in solids content (drying) of only a few percent can double or triple the bulk viscosity of the sediment material. As a result of these experiences, it was not attempted to further increase the solids content of the filter cake, since both blending and pumping into the plasma melter were anticipated to be problems above a bulk viscosity of 100,000 centipoise.

### **5.2.6 Storage and Transfer**

Although not specifically a part of the pretreatment system, the system developed to feed the plasma melter was based on data acquired during the pretreatment phase, and so is discussed here. In addition to influencing the blending strategy and  $\text{Ca(OH)}_2/\text{CaO}$  ratio, the information developed above on sediment viscosity was also invaluable in developing a technique for pumping the sediment mixture into the plasma melter.

The final blended sediment was difficult to characterize rheologically. It had the appearance of damp clay, and could either be crumbled by hand or with gentle pressure be readily molded. At 50-55% solids, the material was sufficiently sticky that it could not reliably be gravity fed, but rather required positive pressure to move. Upon application of shear, however, the material "liquefied" and visibly changed from a dry, clayey material to a shiny, wet-looking viscous fluid. In this form it could readily be pumped with relatively low pressure drop, if a means could be found to feed the sticky, crumbly material into the pump in the first place without bridging and jamming the pump throat.

It is interesting that if water is added and the solids content decreased to below 40%, the sediment flows like a liquid, whereas at 70% solids and above the material behaves like dry soil and could be transported as such. Pumping the lower solids fluid would be simpler, but the economic penalty of heating the additional water to plasma plume temperatures is significant and to be avoided if possible. Between 50 and 60% solids is probably the highest that can be achieved by filtration, with thermal drying required to achieve solids contents at which the material could be handled as a soil. Drying may liberate volatile organic compounds (VOC's) from the sediment, and could require treatment of an additional VOC-contaminated gas

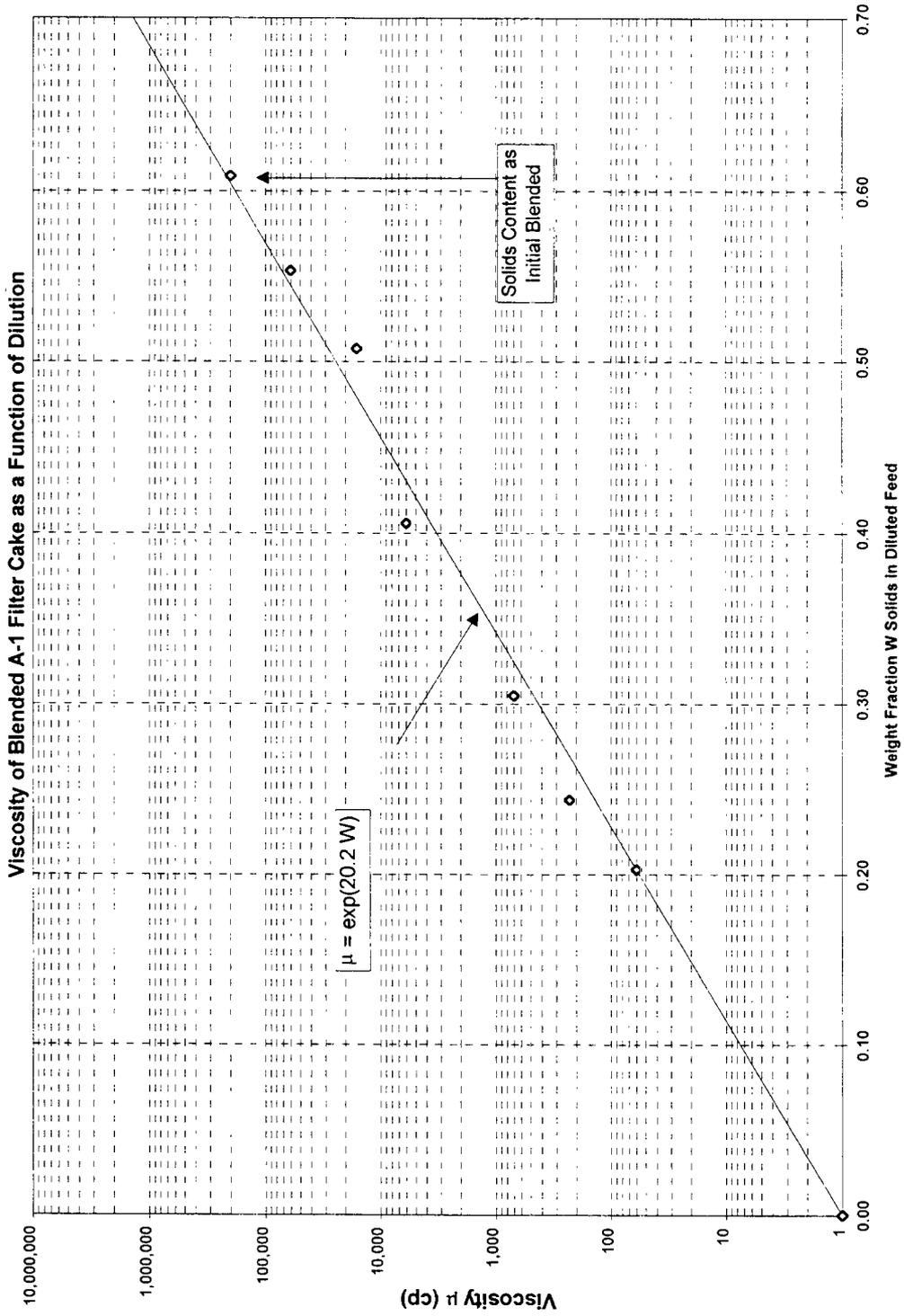


Figure 5.7 Sediment Viscosity as a Function of Solids Content

stream. Pneumatic transport into the plasma melter would then probably be required, which is difficult and introduces significant additional offgas which must be treated. Both of these alternatives are also undesirable. The best option (at least for the pilot test) was therefore to develop a transport system to handle the 50% solids paste.

The final pumping system selected used two Graco 50:1 King pumps, which pumped directly from 55-gallon drums and were capable of providing up to 4 gallons/minute of feed at pressures as high as 4500 psig. The drum pumps which were used could handle material up to approximately a viscosity of 100,000 to 2,000,000 cp. Figure 5.7 data require that the solids content be kept below about 58 %. In some cases, a small amount of water was therefore added back to blended sediment/flux mixture to ensure more reliable pumping.

### 5.3 OVERALL PRETREATMENT MATERIAL BALANCE

The overall material balance is shown in Figure 5.8, showing each rolloff and each press batch individually. The overall material balance around the entire process is summarized in the upper left hand corner for solids and water. For each stream, the total mass, volume of water, and individual masses of solids, salt, and additives are presented. Within each unit operation box, process material balances are presented for solids and water, with the sum of incoming streams given at the left side of the block, and the sum of outgoing streams shown at the right. The five filtrate streams from the press batches are collected in the lower right corner.

#### 5.3.1 Methodology

The pretreatment material balance was computed using measurements of liquid volumes, drum weights, material densities, and solids content analyses. Calculations proceeded as follows.

The initial sediment volume  $V_F$  was computed from the depth profile  $L_F$  and rolloff dimensions, and converted to mass  $M_F$  using measured values of sediment overall density  $\rho_F$ :

$$M_F = \rho_F V_F . \quad (5-1)$$

The mass of solids  $S_F$  associated with the feed material was obtained by analysis of the solids mass fraction  $\sigma_F$  of the sediment:

$$S_F = \sigma_F M_F . \quad (5-2)$$

From an analysis  $x_{NaCl;F}$  of the chloride content of the dry solids fraction, the salt content  $M_{NaCl;F}$  of the feed sediment is also determined:

$$M_{NaCl;F} = S_F x_{NaCl;F} MW(NaCl) / MW(Cl) , \quad (5-3)$$

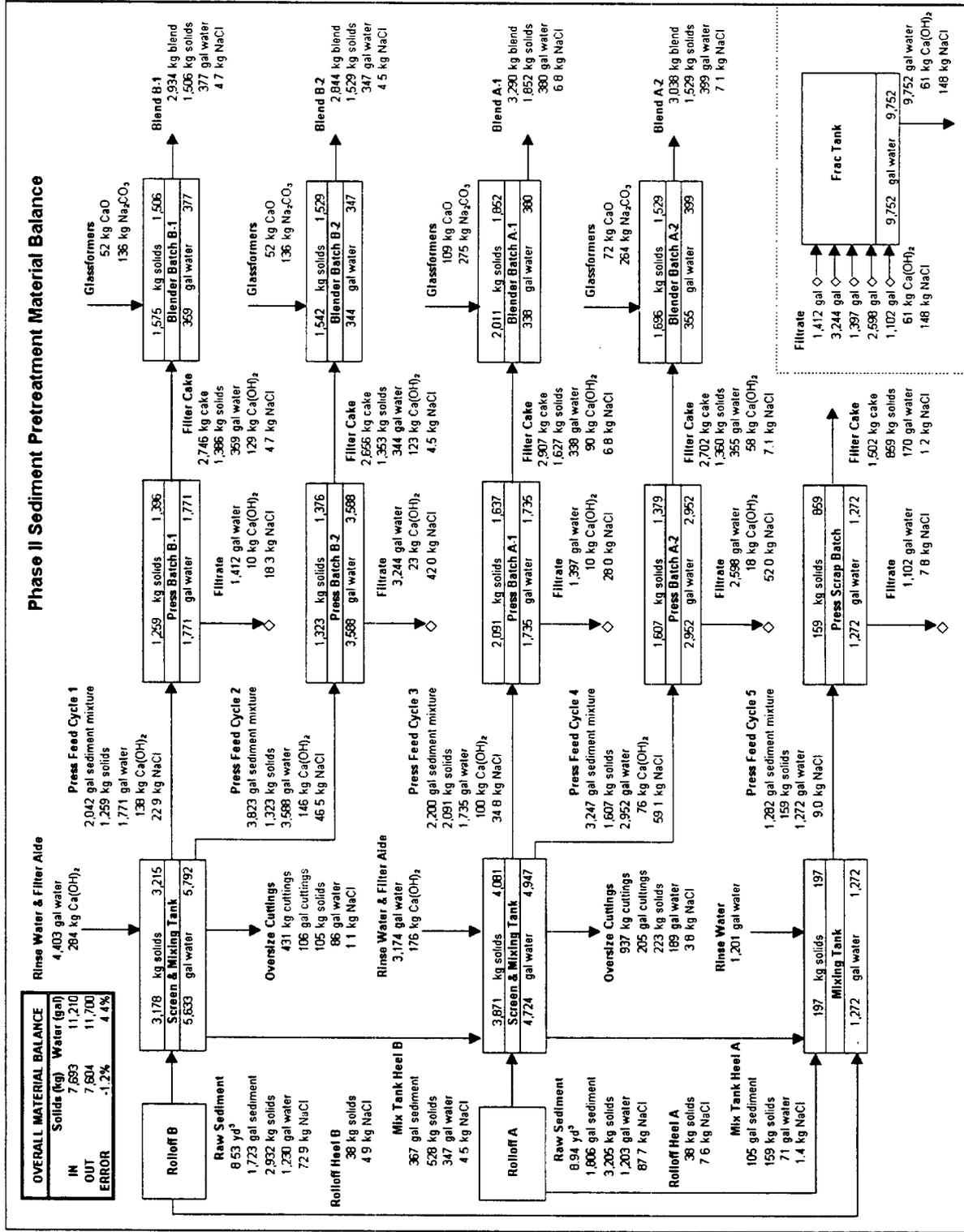


Figure 5.8 Material Balance for Sediment Pretreatment Process

where MW(NaCl) and MW(Cl) are the molecular weights of salt and chloride, respectively.

The mass of oversize cuttings  $M_C$  recovered from the screens was obtained from individual drum weights, with analysis of a composite sample for density  $\rho_C$  and solids content  $\sigma_C$ . From the difference of total cuttings mass and solids mass, the mass of water associated with the oversize material was determined. The mass of undersize sediment feed  $M_{UF}$  transferred to the mixing tank was then determined by difference:

$$M_{UF} = M_F - M_C . \quad (5-4)$$

The volume of slurry  $V_S$  in the mixing tank is determined directly by measurement of the liquid depth and the tank strapping factor  $\epsilon$  (gallons/inch of depth). From the difference of this volume, the original feed volume, the feed heel  $V_{FH}$  remaining in the rollofs, and the known volume of cuttings  $V_C$ , the volume  $V_{RW}$  of rinse and sluice water added may now be determined:

$$V_{RW} = V_S - (V_F - V_{FH} - V_C) . \quad (5-5)$$

The total mass of slurry  $M_S$  now in the mix tank and the solids content thereof could now be determined by either

1. The known volume of slurry in the mix tank multiplied by the density of a grab sample  $\rho_S$ , and/or its measured solids content  $\sigma_S$ , or
2. By difference of the solids determined in the rolloff feed  $S_F$  less the solids remaining in the rolloff heel,  $S_H$ .

This latter was determined by measurement of the depth of heel remaining in the rollofs and its measured solids content  $\sigma_H$ . Both approaches were computed, and differed substantially. It was decided that the tank impeller was not sufficiently energetic to maintain a fully homogeneous suspension, so that the value of  $\rho_S$  measured from a grab sample was too low. The heel volume was rather small as a fraction of the total, and so introduced less error. Thus

$$M_S = M_F + M_{RW} - M_C - M_{FH} , \quad (5-6)$$

with a similar determination of the solids content  $S_S$  of the slurry.

The lime filter aide addition  $M_G$  to Rolloff B sediment was based on 0.10 lb/gallon, whereas that for Rolloff A was set at 0.075 lb/gallon, as discussed previously. To determine the mass of sediment and solids delivered to the filter presses, again the choice had to be made whether to compute this using analysis of the slurry, or by difference. As before, computation by difference was believed to give more accurate results. Therefore, the mass of feed to the press  $M_M$  was determined from

$$M_M = M_S + M_G - M_{SH} , \quad (5-7)$$

where  $M_{SH}$  is the slurry heel left in the mixing tank. The solids  $S_M$  transferred with the filter press feed are computed similarly, and the water volume  $V_{MW}$  associated with the filter feed is computed from the difference of  $M_M$  and  $S_M$ , divided by the density  $\rho_w$  of water.

Material balancing around the filter press operation is done directly from analytical data on each filter cake,  $\rho_K$  and  $\sigma_K$ . The volume of filter cake from each press drop is known from the internal volume  $V_K$  of the press frames (2.74 cy), so that measurement of the cake density provides the total weight of cake collected without the need to drum the entire inventory and measure each drum:

$$M_K = \rho_K V_K. \quad (5-8)$$

The solids content  $S_K$  of the filter cake is therefore known from the computed weight  $M_K$  of the collected cake and its solids content. The volume  $V_{XW}$  of filtrate water is also not conveniently measured, since the filter press delivers this directly to the frac tank. This may be computed, however, from the volume of water  $V_{MW}$  delivered to the press less the water content  $V_{KW}$  of the filter cake:

$$V_{XW} = V_{MW} - (M_K - S_K) / \rho_w. \quad (5-9)$$

Material balance over NaCl is done assuming that salt follows water; wherever a split occurs, the fraction of NaCl in each stream is the same as the split in the water content. A similar calculation is carried out for  $\text{Ca}(\text{OH})_2$ , recognizing that hydrated lime has a significant solubility in water (approximately 0.007 kg/gallon at ambient temperature); once added to the mixing tank, the soluble calcium hydroxide content of each stream is partitioned along with the water, while the insoluble  $\text{Ca}(\text{OH})_2$  remains with the solids.

Finally, in the flux addition step, chemical reaction between water and CaO is assumed to form  $\text{Ca}(\text{OH})_2$ , reducing the free water content of the sediment. No effort is made to account for evaporative loss of water due to the exothermic nature of this reaction.

### 5.3.2 Material Balance Closure

The overall material balance shown Figure 5.8 is seen to close within 3.5% on total solids (sediment plus additives), and within 3.6% for water. Given the number of assumptions involved and the scatter in the analytical data, this closure is excellent. Closure of material balances around individual batch unit operations is not as good, and may represent variability in sampling and analytical procedure.

Table 5.4 summarizes the important results from this detailed material balance. Note that the values reported are for the sum of the four sediment batches, and do not include the heel batch; this latter processing step required unusually large volumes of rinse water (its purpose being cleaning of the

Table 5.4 Summary of Pretreatment Material Balance

Parameter	Value
Sediment Processed, cy	17.47
Sediment Processed, kg wet	16,711
Sediment Solids Processed, kg dry	6,136
Oversize Cuttings Removed, kg dry	328
Oversize Dry Solids Rejection, w/o	5.35
NaCl in Feed Sediment, kg	160.6
NaCl in Blended Melter Feed, kg	23.1
Salt Rejection, w/o	85.62
Rinse/Sluice Water Consumption, gal (kg)	7,577 (28,654)
Hydrated Lime Consumption, kg	460
Volume of Slurry Filtered, gal (kg)	11,312 (42,778)
Average Solids Content of Filter Feed, w/o	10.93
Filtrate Water Produced, gal (kg)	8,651 (32,715)
Mass of Filter Cake Produced, kg	11,011
Filter Cake Solids Content, w/o	52.00
CaO Flux Added, kg	285.0
Na <sub>2</sub> CO <sub>3</sub> Flux Added, kg	811.0
Blended Melter Feed Produced, kg	13,608
Blended Melter Feed Solids Content, w/o	53.53
Blended Melter Feed Salt Content, w/o	0.20

equipment) and relatively little sediment, and therefore is not representative of normal operation.

A total of 17.5 cubic yards of sediment were received from Brookhaven and were converted to melter feed. A little over 5% by weight of the dry solids content of the sediment represented material over 1 mm, most of it leaves, sticks, and man-made trash; very little gravel or sand particles in excess of this size were found.

Screening, rinsing, of the sediment initially increased the water content of the sediment from 63% up to 90%. A total of 11,300 gallons of sediment slurry were then successfully dewatered, produced a filter cake having a water content of 47%. The resultant rejection of salt was nearly 86%, and produced a plasma feed containing only 0.2% by weight NaCl. Fluxes were added to Rolloff B making a feed designed to produce a glass having 83% sediment metal oxide loading, while Rolloff A was blended to produce a glass having a slightly lower 77% loading, and anticipated lower processing temperature. The final yield of blended melter feed was 13,600 kg at an average solids content of 53.5%, which was drummed and stored pending processing with the plasma melter.

## 6. SEDIMENT VITRIFICATION OPERATIONS

Sediment vitrification operations consisted of three tests carried out on October 23, November 7, and December 5, 1996. The first two runs consisted of equipment shakedown tests, focusing on feed delivery to the plasma melter, and design of the molten glass extraction system. Following these tests modifications were made to both the system configuration and the process chemistry. The third Demonstration Test was conducted without significant difficulties in either feed delivery or product extraction, and successfully demonstrated pilot-scale harbor sediment vitrification at a pilot scale of 5.5 tons/day of glass production (15.0 tons/day equivalent as-dredged sediment processing).

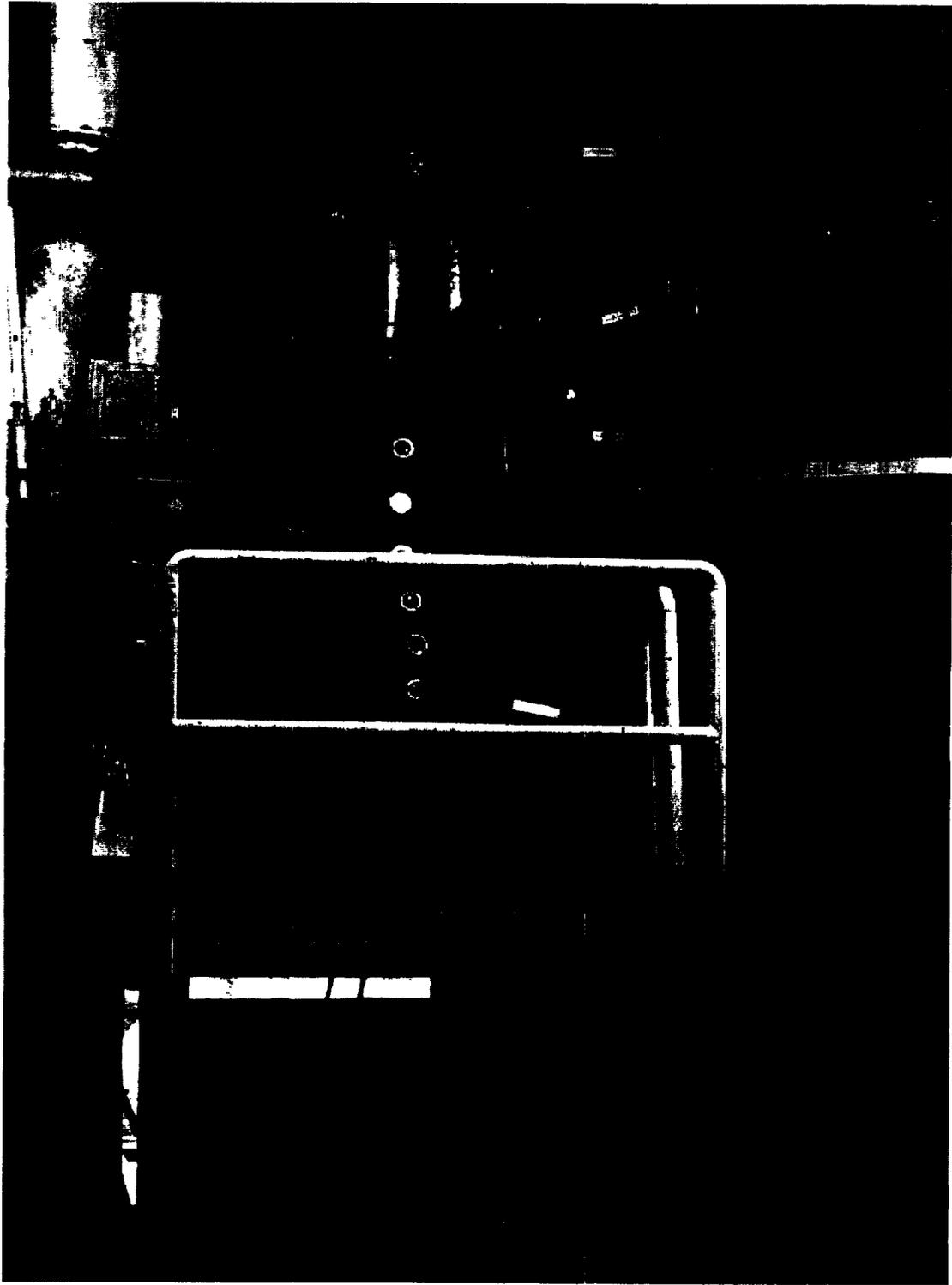
### 6.1 OPERATIONAL PROCEDURES

For each of the three tests, the same series of basic procedures was followed, consisting of melter refractory preparation, plasma system testing, feed system preparation, initialization of the offgas handling system, and setup of the product recovery system. Instrument calibration and system cleanout were carried out more rigorously for the Demonstration Test 3 than for the two shakedown runs.

#### 6.1.1 Refractory Preparation

The melter itself was first prepared for testing. This involved cleaning out of the shaft (shown in the center of Figure 6.1), removing any material or loose refractory from previous testing, and repairing any damage. Refractory patching was done with Premier Refractories and Chemicals 90-RAM-PC, a common blast furnace refractory material, having a composition of 91%  $\text{Al}_2\text{O}_3$ , 5%  $\text{SiO}_2$ , and 3%  $\text{P}_2\text{O}_5$ .

The crucible and tuyere refractory were then prepared for testing. In the case of the tuyere, a new cast refractory lining was installed inside the water-cooled steel tube. The refractory used (Harbison-Walker Castolast-G) had a composition consisting of 93%  $\text{Al}_2\text{O}_3$  and 7%  $\text{CaO}$ , which historically has proven to be highly durable at very high temperature. This particular refractory does not have exceptional resistance to molten glass, however, and some alumina uptake was always noted during testing, especially during the early phase of each test. Eventually thinning of the refractory reached a steady-state level, with the final tuyere lining consisting of a layer of frozen glass inside the thinned calcia-alumina.



**Figure 6.1 - Plasma Melter System**

The crucible was then prepared by removing old refractory, and refilling the shell with Harbison-Walker Ruby Plastic refractory (75%  $\text{Al}_2\text{O}_3$ , 19%  $\text{Cr}_2\text{O}_3$ , 2%  $\text{SiO}_2$ , and 4%  $\text{P}_2\text{O}_5$  binder). This material has been shown to have significantly superior resistance to molten glass than the alumina-calcia refractory, and is used for a number of applications where high durability is required. The use of a plastic moldable material allows the contours of the crucible to be customized to provide the desired residence time in the crucible pool, as well as designing the drain path to the product extraction system.

Ruby refractory is not commonly used in the glass industry, due to chromium pickup by the glass and the end-of-life cost hazardous waste associated with disposal of refractory containing Cr(VI). Alumina-silica is also avoided, due to inadequate resistance to dissolution by molten glass. Commercial glassmaking furnaces typically use AZS (alumina-zirconia-silica) refractory which has excellent molten glass resistance, but is not available in a plastic form. The cost and time requirements of relining the Westinghouse melter with AZS brick and cast preforms were outside the scope of the Demonstration Test. A mixture of ruby and Castolast refractories, therefore, was used. We expected, however, elevated Al and Cr levels in the glass product to result from this refractory choice.

Tests 1 and 2 were carried out with longer (30 to 45 minute) residence times designed into the crucible configuration, while Test 3 was designed with a minimal crucible holdup time (no more than 5 minutes).

### 6.1.2 Instrumentation Calibration

At the same time that the refractory was repaired, all thermocouples and other instruments were checked out and calibrated, and repair or replacement made to any instrument not functioning properly. Melter instrumentation is shown in Figure 6.2, and consisted of eighteen thermocouples (T) in the shaft and pour spout, seven pressure monitors (P) in the shaft, flowmeters (F), and offgas composition analyzers for four gas components ( $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{O}_2$ , and  $\text{NO}_x$ ). Note that in the current test operations the afterburners at the top of the shaft were not used, in that no combustible gases were formed in the reaction. Similarly, the charge door was also not used, and remained sealed during the entire test program.

Finally, the plasma system instrumentation was tested, including the torch itself. To ensure reliable operation, two torches were assembled and test fired in the open laboratory to ensure proper operation of the power supplies and all torch utilities. Once both torches were fully qualified according to standard Plasma Center procedures, one was placed in standby and the second mounted on the melter tuyere.

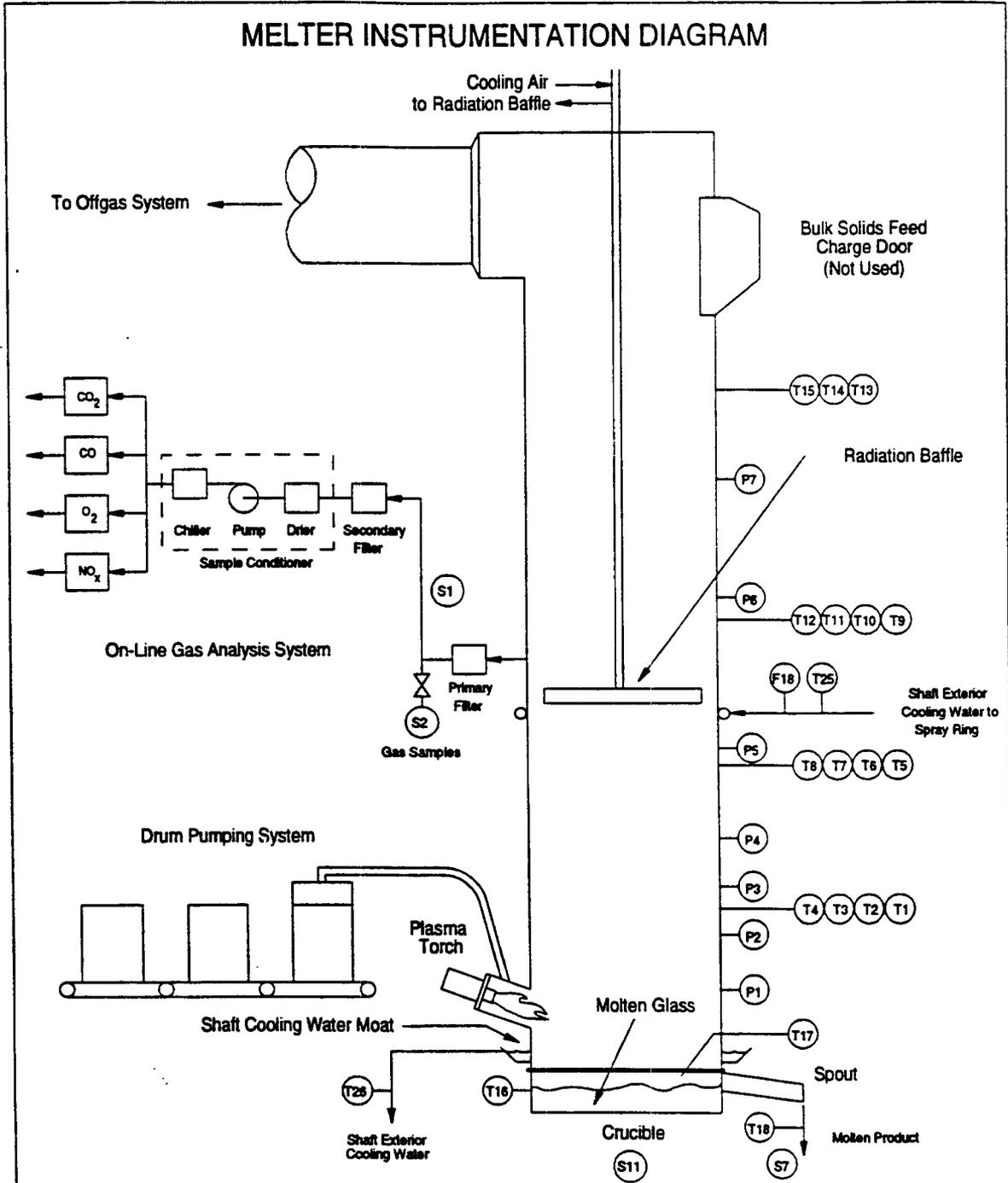


Figure 6.2 Plasma Melter Instrumentation Diagram

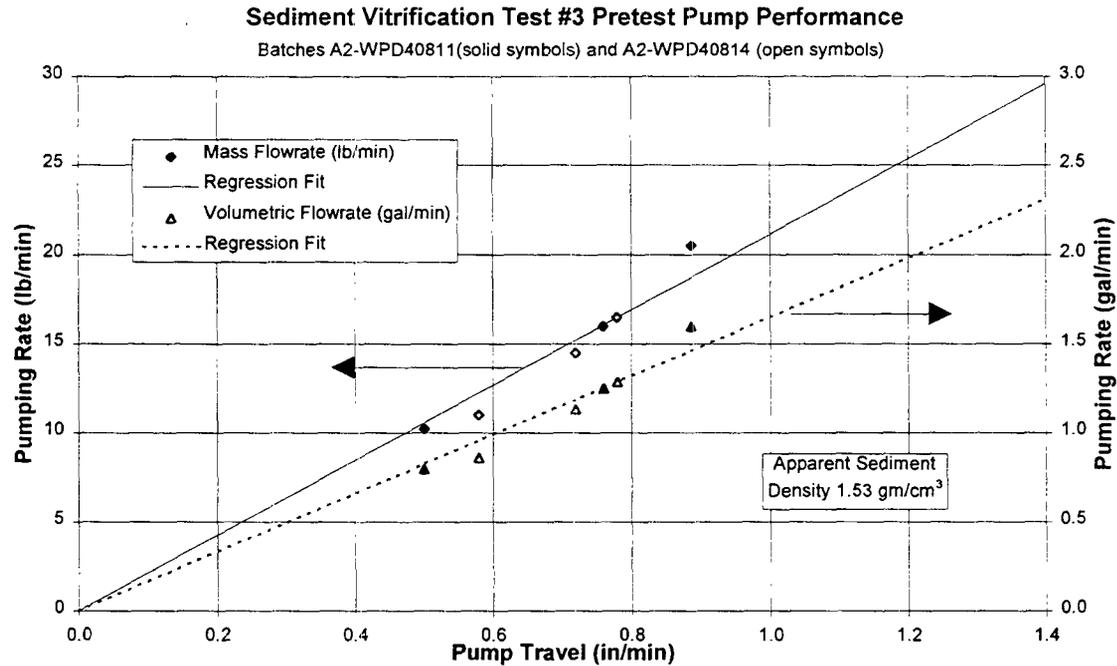
### 6.1.3 Feed System Calibration

The feed system was assembled and tested. A conveyor transported drums of blended sediment from the storage area to the drum pumps. As indicated in Section 4.2, two Graco 50:1 King pumps were used, with one operational and the second in standby mode. The feed pumping system is shown in Figure 6.3. These pumps are designed to provide positive pumping action directly from 55-gallon drums at very high pressure, and are therefore capable of delivering extremely viscous fluids at viscosities of 100,000 to 2,000,000 cp. A sealed ram moves slowly into the drum, while a pickup receiver plunges into the sediment and draws batches of material up into the pump on each stroke, discharging it at pressures up to 4500 psig.



**Figure 6.3 - Drum Pump Sediment Feed System**

Since the ram represents a positive displacement, the volumetric feed rate of the pump may be calibrated against the downward travel velocity of the ram. Prior to the start of Test 3, the Graco pumps were calibrated against sediment blend A-2, with the results shown in Figure 6.4. Although some scatter is apparent, the calibration is generally good, and this curve was used to establish the desired sediment blend feed rate into the melter.



**Figure 6.4 - Drum Pump Calibration Curve**

#### 6.1.4 Product Collection System

At the other end of the process, sand-lined steel mold boxes were prepared to receive the molten glass; one appears positioned below the melter Figure 6.1. These steel boxes were ram-packed with mill sand as a thermal protection, and to facilitate removal of the solidified glass product. The boxes were then mounted on rail skids for positioning under the melter pour spout.

The slag quench system was also prepared, consisting of a closed box with a port for pouring of molten glass, and a high-velocity recirculating water injection system to impact the glass stream and fragment it into small granules. A known volume of water was added, and the temperature of the liquid recorded.

### 6.1.5 Scrubber System

Before testing, the scrubber system was completely cleaned, and the recirculation tank was refilled with clean water. The tank was "strapped" to determine the volume as a function of depth, and the initial water depth recorded. During the testing, the level of liquid in the tank changed continuously due to condensation of combustion product steam from the sediment, and loss of liquid due to evaporation and air stripping. The scrubber tanks are shown in Figure 6.5.

Since sodium is lost from the system due to volatilization of NaCl and NaOH, closing the material balance on sodium requires knowledge of the Na content of the scrubbing system as a function of time. By analysis of the tank sodium concentration and its volume, the time-dependent inventory can be determined, and the rate of sodium loss from the system calculated. In general, the liquid level would increase during plasma torch operation. The level of liquid in the tank was regularly recorded.



**Figure 6.5 - Scrubber System Recirculation Tanks**

Absorption of CO<sub>2</sub> and NO<sub>x</sub> from the plasma offgases also continuously reduced the pH of the scrubber tank, requiring regular injections of alkali to maintain a nearly neutral pH. For this purpose KOH was used, to avoid masking the effect of sodium buildup.

### 6.1.6 System Startup and Operation

Initial heatup of the melter system was accomplished over about four hours, using both the plasma torch at reduced 950 kWe power and methane injection. Use of CH<sub>4</sub> injection not only provides combustion heat, but the carbon dioxide and steam produced greatly increase the emissivity of the resulting gas mixture and enhance the heating properties of the plasma plume. Methane was discontinued once sediment feed was introduced to avoid confounding the CO<sub>2</sub> data from sediment organic combustion.

Sediment was not injected until the lower shaft temperature had reached 1350°C, to avoid possible accumulation of viscous glassy material which could block the tap hole. Feed was started at the full 20 lb/min flowrate once the melter was hot, with the plasma torch power elevated to the steady state value of 1500 to 1600 kWe. Operation continued until the desired quantity of material had been processed, or until a stopping point agreed upon mutually by the test engineers involved.

## 6.2 SHAKEDOWN TEST 1

The first shakedown test was carried out on October 23, 1996, and focused primarily on demonstration of the feed delivery system. The material fed was blend Batch B-1, consisting of sediment from Rolloff B blended to 83% loading and as high as 58% solids. Parameters are summarized in Table 6.1.

**Table 6.1 Summary of Shakedown Test 1 Operations**

Total Sediment Feed (lb)	391
Duration of Feed (hr)	3.25
Feed Rate (lb/min)	3.9
Feed Batch	B-1
Solids Content (w/o)	58
Sediment Loading (w/o)	83
Torch Power (kW)	1500 to 1700
Total Tuyere Air Flow (scfm)	510
Product Discharge Temperature (°C)	~1200

### **6.2.1 Test 1 Operations**

Test 1 was conducted with the goal of pumping the highest solids content practical, which in turn introduced difficulties in operating the drum pumps. In part as a result of feed difficulties, the test was of short duration (only 3.25 hours). Because it was so difficult to transport the viscous 58% solids, the low feed rate resulted in a high specific power (kWe per lb/min of feed). This factor in turn resulted in a high loss of sodium from the mixture, and a very viscous glass melt. Viscosity was also increased by incorporation of refractory alumina from the tuyere. Loss of refractory always occurs, but in general the throughput is high enough that the small quantity of alumina is diluted in a large quantity of product melt, and the impact on melting temperature is minimal. In this case, the total glass produced was only 391 lb, and the  $\text{Al}_2\text{O}_3$  from the tuyere had a substantial impact on the product.

The product extraction system typically used in the Plasma Vitrification Pilot Plant involves a bottom tap which passes under a notch, creating a liquid seal. This pour hole was unheated (except for heat provided by the flowing glass). Although this design works very well for metal melting and pouring of low-silica slags, it resulted in plugging with our sediment glass, and little product could be removed through the tap. At the point that the test was discontinued, essentially all of the molten product had accumulated in the crucible. It was later removed as a solid mass when the crucible was dropped.

### **6.2.2 Conclusions Based on Test 1 Experience**

As a result of analysis of the results of Test 1, several modifications were made to the operating strategy. Additional water was blended into the Test 2 feed to reduce the feed viscosity, which was expected to make drum pumping significantly more reliable and permit operation at higher feed flow rates. The loading was also decreased by addition of more lime and soda ash, increasing the ratio of Na to Ca.

## **6.3 SHAKEDOWN TEST 2**

The second shakedown test was carried out on November 7, 1996, and used blended material A-1 with added water and fluxes. Test parameters are summarized in Table 6.2.

### **6.3.1 Test 2 Operations**

The strategy of reducing the solids content of the feed from 58% down to 55% was highly successful, and minimal difficulty was encountered in the operation of the drum pumps. As a result, the average feed rate was increased from 3.9 lb/min

**Table 6.2 Summary of Shakedown Test 2 Operations**

Total Sediment Feed (lb)	2655
Total Glass Product Generated (lb)	985
Duration of Feed (hr)	5.25
Feed Rate (lb/min)	8.5 to 22
Feed Batch	Reblended A-1
Solids Content (w/o)	55
Sediment Loading (w/o)	76.7
Torch Power (kW)	1500
Total Tuyere Air Flow (scfm)	600
Product Discharge Temperature (°C)	~1150

during Test 1 up to 8.5 lb/min average, with steady state operation near the end of the test at 22 lb/min achieved. The reduced loading was also successful at reducing the melt viscosity, and nearly 1000 lb of molten product were recovered from the melter.

Removal of the molten glass still proved to be difficult, again due to the over-under design of the pour spout and the lack of direct heat input to the pour spout. Although product flowed from the melter, the glass would tend to chill in the spout, and result in blockages. The product discharge temperature as measured by an immersion thermocouple in the spout was only 1150°C, although the glass had originally been blended for 1300°C melting at 100 poise viscosity.

Figure 6.6 shows an analysis of the product glass composition by electron microscopy Energy Dispersive Spectroscopy (EDS); this analysis is only semiquantitative for elements as light as sodium. The composition of the resulting glass product was very close to the target, with the expected exception of some loss of volatile sodium; the target Na<sub>2</sub>O content was 12.5%, whereas actual analyses of the glass product indicated soda contents of between 9 and 11%. These data imply sodium retention of about 80 to 90%. Alumina was also somewhat elevated with respect to the target due to refractory pickup.

The actual loss of sodium to the offgas system is shown in Figure 6.7, based on cumulative analysis of the scrubber water for sodium content. During most of the test the rate of accumulation of Na in the offgas recirculating scrubber tank was 250 gm/hr, or 0.55 lb/hr. Given an average sediment feed rate of 8.5 lb/min (510 lb/hr) at a solids content of 55% and a solids Na<sub>2</sub>O concentration of 2.9%, the total rate at which Na was fed to the melter was:

$$(510 \text{ lb/hr})(0.55 \text{ lb solids/lb})(0.029 \text{ lb Na}_2\text{O/lb solids})(46 \text{ lb Na}/62 \text{ lb Na}_2\text{O}) = 6.0 \text{ lb/hr Na.}$$

Composition of Sediment Vitrification Test #2 Product

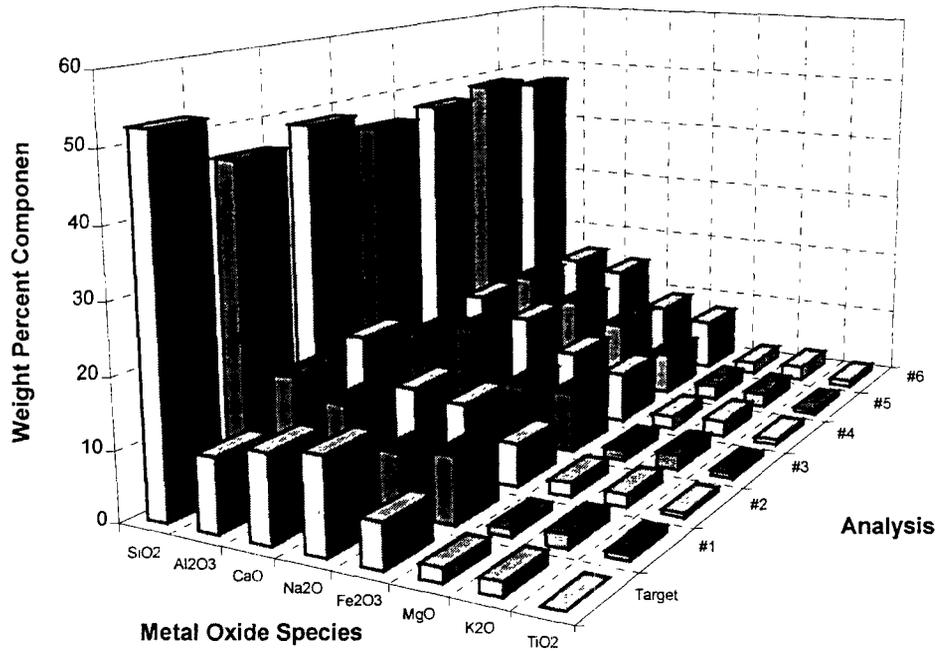


Figure 6.6 - Composition of Glass Product from Shakedown Test 2

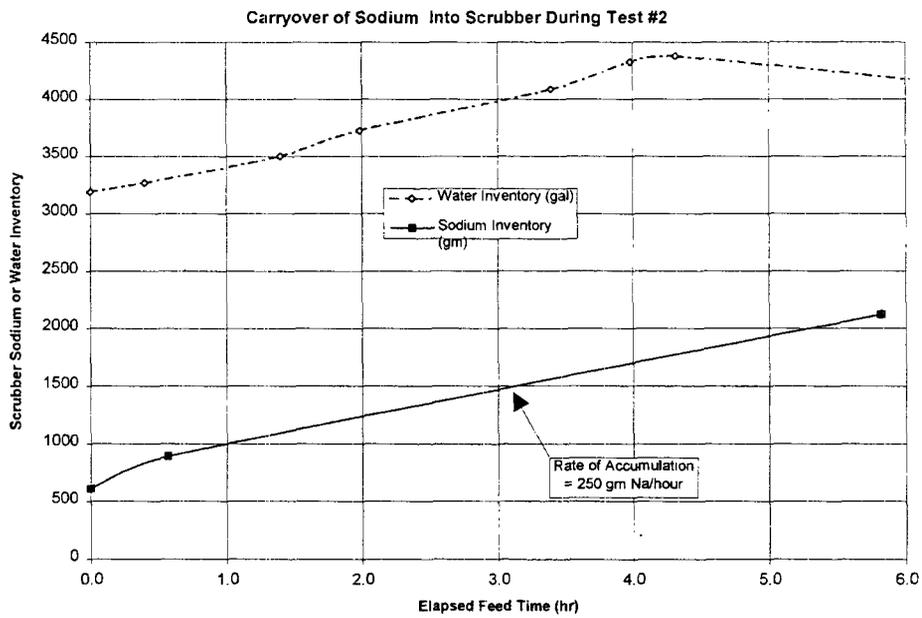


Figure 6.7 - Sodium Loss to the Offgas During Shakedown Test 2

The overall retention was, therefore, 90.8%, in qualitative agreement with the 80 to 90% derived from EDS analysis.

### 6.3.2 Conclusions Based on Test 2 Experience

The strategy of lower solids content to facilitate drum pumping, and slightly lower sediment loading to increase the soda and calcia content and reduce the melt viscosity were together successful at improving processability and making continuous operation possible. A total of eight drums were successfully vitrified during Test 2, with nearly 91% retention of sodium.

Although the feed issues were largely resolved by the conclusion of Test 2, removal of glass product from the melter still posed some difficulty. We decided to simplify the design of the pour spout for the final demonstration test. The spout was removed, and a simple penetration into the lower portion of the crucible was designed to directly drain the melt. The residence time in the crucible was minimized by this design change, however, so that the possibility existed of a less homogeneous melt than might have otherwise been produced with longer time for blending.

### 6.4 DEMONSTRATION TEST 3

The final Demonstration test (Test 3) was carried out on December 5, 1996. The sediment feed was blended material Batch A-2 (15 drums, processed first) with added water and fluxes as compared to the original recipe and Batch B-1 (6 drums). Test parameters are summarized in Table 6.3.

Table 6.3 Summary of Test 3 Operations

Feed Batches	"Reblended A-2" and B-1
Total Sediment Feed (lb)	6137 (A-2); 2621 (B-1) 8758 (Total)
Total Glass Product Generated (lb)	2495 (Bulk Casting); 466 (Quenched) 16 Pancakes; 401 Estimated Holdup = 3388 Total
Duration of Feed (hr)	7.65
Feed Rate (lb/min)	20.1 (A-2); 19.4 (B-1)= 19.58 (Average)
Solids Content (w/o)	50.3 (A-2); 51.3 (B-1)
Sediment Loading (w/o)	76.9 (A-2); 83.2 (B-1)
Torch Power (kWe)	1600 (Average; reduced to 1500 during last hour)
Total Tuyere Air Flow (scfm)	450 (reduced to 350 during last hour)

### 6.4.1 Test 3 Operations

Test operations began at 06:45 with torch ignition. System heatup continued over the next 3.5 hours until the crucible inner wall temperature reached 1350°C. At this point, feed injection began and the torch power raised to 1600 kWe. Batch A-2 sediment was fed first, processing 15 drums. Molten material appeared at the pour spout approximately 65 minutes after initiation of feed, during this period an inventory of glass was accumulating on the relatively cool walls of the melter and the floor of the crucible. Batch A-2 processing continued for 310 minutes. The feed material was then changed over to Batch B-1, having a higher sediment loading (i.e., higher melting point) and greater solids content than Batch A-2. Batch B-1 processing continued for an additional 150 minutes.

Feed flowrates are presented in Figure 6.8. It is seen from the linearity of the cumulative feed injection curve that despite the difficulties encountered during the shakedown tests, the feed injection rate was maintained at a constant level throughout Test 3. The overall average feed rate was 19.6 lb/min, while the average of the individual drum feed rates was 19.3±3.3 lb/min; fluctuations about the mean were therefore kept to within a standard deviation of ±17%.

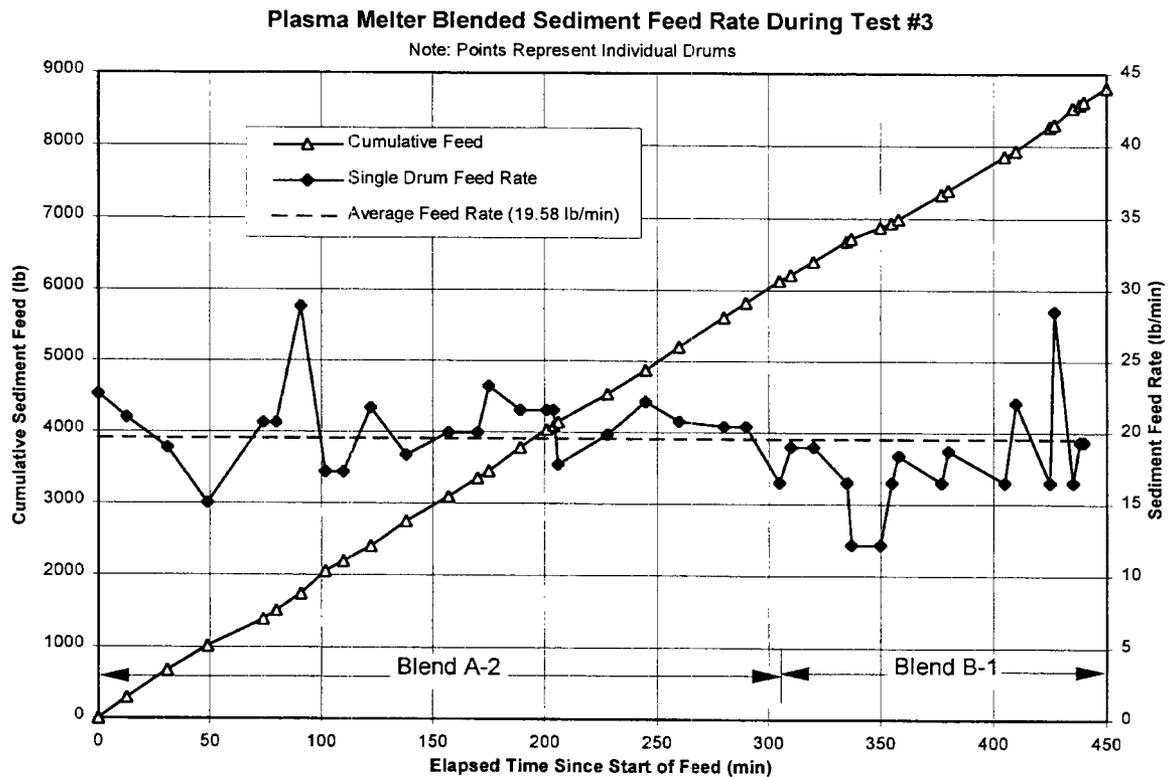


Figure 6.8 - Feed Flowrates During Demonstration Test 3

Feed material parameters are summarized in Table 6.4, where the overall chemical compositions of the feed materials are summarized. The compositions of the two batches differed somewhat, with the most notable difference being the

**Table 6.4 Sediment, Feed, and Glass Compositions Processed During Test 3**

Sediment Composition:	Batch A-2			Batch B-1		
	Dry Sediment	Dry Feed	Glass	Dry Sediment	Dry Feed	Glass
SiO <sub>2</sub>	54.54	41.38	51.78	52.33	43.64	54.34
Al <sub>2</sub> O <sub>3</sub>	11.03	8.19	10.66	10.93	9.13	11.35
Fe <sub>2</sub> O <sub>3</sub>	6.66	4.94	6.43	6.45	5.38	6.70
CaO	1.96	1.45	11.93	2.01	1.68	13.28
MgO	2.14	1.59	2.07	2.22	1.85	2.30
Na <sub>2</sub> O	1.76	1.31	14.21	3.00	2.51	8.71
K <sub>2</sub> O	2.06	1.53	1.99	2.18	1.81	2.26
TiO <sub>2</sub>	0.81	0.60	0.78	0.82	0.69	0.85
CuO/ZnO	0.16	0.12	0.15	0.19	0.16	0.20
NaCl	2.61	0.31		2.64	0.31	
S	2.78	2.06		3.23	2.70	
C/H/O/N	12.12	8.99		12.62	10.52	
Hydrate H <sub>2</sub> O	1.36	1.01		1.38	1.16	
<b>Fluxes</b>						
Ca(OH) <sub>2</sub>		3.67			7.41	
CaO		4.94			3.39	
Na <sub>2</sub> CO <sub>3</sub>		17.18			7.69	
<b>Total</b>	100.0	100.0	100.0	100.0	100.0	100.0
Sediment Loading	76.9%			83.2%		
Solids Content	50.3%			51.5%		

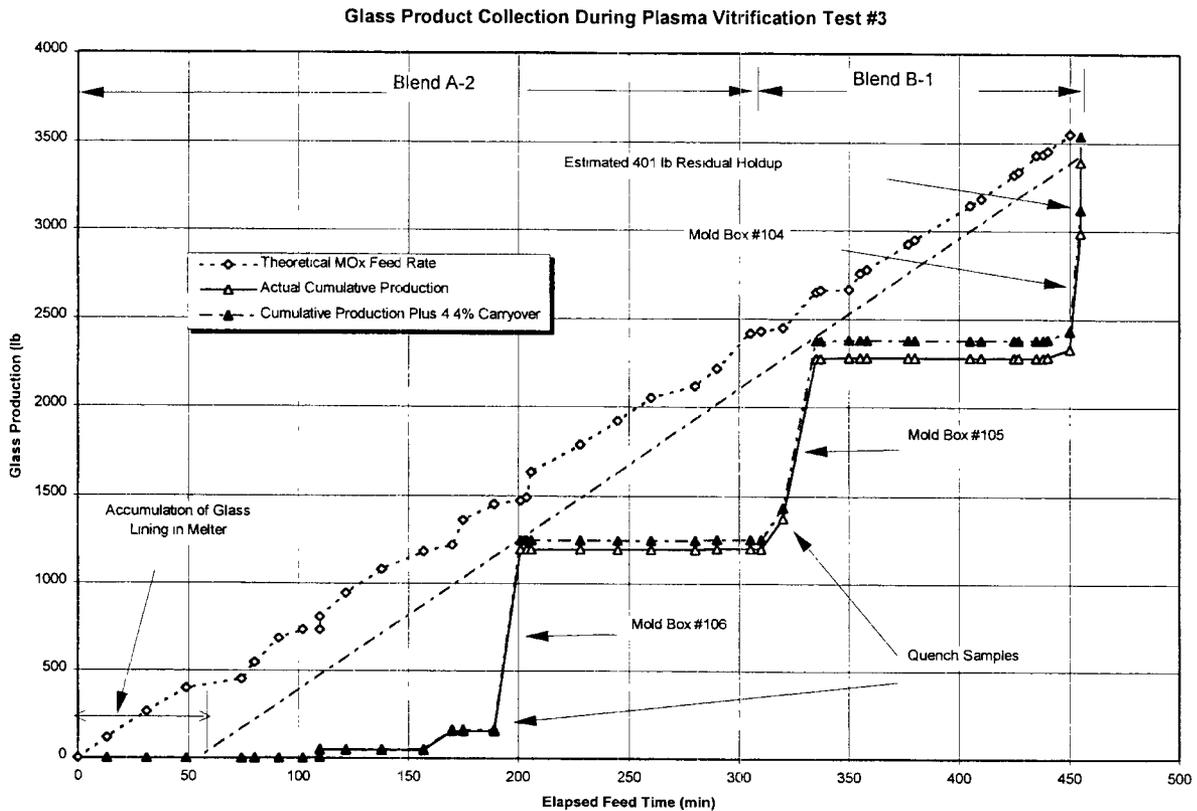
higher sodium content of the Batch A-2 sediment material. As blended, the A-2 material was provided significantly higher sodium content, so that the melting point and viscosity of the glass formed from this material were expected to be significantly lower than for the B-1 feed processed later in the test. Despite the increased melting temperature, B-1 sediment feed was successfully processed for nearly three hours with no increase in the plasma torch power, it was maintained at a constant 1600 kWe throughout the test.

#### 6.4.2 Product Accumulation

Once the melting process had begun, operations continued smoothly with little or no difficulty with either drum pump operation or product recovery. The glass poured smoothly and evenly with an estimated pour temperature of 1200 to 1250°C based on color. Three mold boxes were filled with glass, two with Batch A-2 (Boxes 106 and 105) and one with blend B-1 (Box 104), collecting a total of 2500 lb of bulk glass castings. A small quantity of residual glass was accumulated in mold Box 103 following shutdown of the plasma torch, and additional glass was left behind as a coating on the interior of the melter and crucible. From the melter geometry and measurements of glass lining thickness, the mass of residual glass is estimated at 401 lb.

Glass accumulation is shown in Figure 6.9. Collection of glass appears in steps, logged in as each mold box was removed from the melter and weighed. Also shown is the theoretical quantity of glass anticipated from the feed injection, measured solids content, and chemistry of the feed. At the end of the test the two values (i.e., actual and theoretical) agree within 4.7%. As reported in Section 7.3.4, roughly 4.4% of the feed solids are estimated to have been entrained into the offgas from analysis of the TSS in the scrubber; this leaves only 0.3% of the glass unaccounted for. In all likelihood this material represents the error in estimating the holdup volume, increasing the best estimate value of melter holdup from 401 lb up to 411 lb. This latter value is shown in the figure. Examination of the mold box accumulation rate suggests that most of the melter holdup occurred during the first hour of feed, when the crucible, tuyere, and melter shaft were collecting a steady-state layer of glass and increasing to the final steady-state temperature. Once this initial accumulation had occurred, the slope of the mold box collection curve matches that of the theoretical glass production curve.

Samples of the glass were taken regularly throughout the test by collecting a molten "pancake" of glass on a slag plate, and cooling gradually within an insulated blanket to avoid shattering. Most of the samples collected in this way did fragment nevertheless; to obtain stable pancake samples would require use of an annealing oven to relieve internal stresses in the glass. A total of about 16 lb of pancake samples was collected.



**Figure 6.9 - Product Glass Collection for Test 3**

Quench samples were also collected. Recirculation was started up in the quench box, and ladles of molten glass poured into it. Roughly 325 lb of A-2 glass granules were produced in this way, at which point the quencher was shut down and emptied, recovering the glass in 5 gallon drums. The quencher was then refilled with water, restarted, and another 141 lb of B-1 glass granules produced. A total of 466 lb of quenched glass granules was therefore produced by direct water quench, and are also shown in Figure 6.9.

Assuming that the 401 lb of estimated glass holdup in the melter is correct, the total glass production during Test 3 was 3388 lb, over a total operation time of 460 minutes. The glass production rate was therefore 7.37 lb/min, or 5.30 ton/day at full plant factor. The higher holdup value of 523 lb would increase the total glass production to 3510 lb, or 5.49 ton/day. Note that this latter figure corresponds to 15.0 tons/day equivalent processing of as-dredged sediment.

### **6.4.3 Low-Shroud-Flow Testing**

Approximately 1.5 hours into the processing of B-1 material, a test was done in which the shroud gas flow was reduced. Reduction of total blast air is highly desirable economically for a number of reasons. Lower air flow reduces the total energy input required to achieve a given tuyere temperature, saving power costs. Reduced air flow also lowers the volume of offgas which must be treated, reducing the size and capital cost of gas treatment equipment. The reduced air flow also slows the flow velocity through the tuyere, allowing the feed a greater residence time at maximum temperature for mixing and fusion. Finally, the reduced air flow in the melter shaft leads to lower solids entrainment into the offgas. Prior testing had been carried out with 150 scfm of torch air plus 300 scfm of shroud air for a total blast air volumetric flowrate of 450 scfm.

During the last hour of B-1 operation, therefore, the shroud gas was reduced to 200 scfm, lowering the total air flow to 350 scfm. The viscosity of the glass decreased noticeably during this point, with an estimated pour temperature of 1350°C based on color. Operation was maintained within allowable control limits, indicating that low-shroud-air processing is, indeed, feasible.

### **6.4.4 Low-Power Testing**

Further testing of the limits for sediment processing was carried out at the end of the test. The plasma torch power was reduced from 1600 kW down to 1500 kW. Although some increase in melt viscosity was visually observed, processing still continued smoothly and without interruption. Note that this positive result was obtained even though operating with the higher melting B-1 material. Although this test was relatively brief, the response time of the plasma melter is very short. If excessive melt viscosity were to result from 1500 kW operation, the results would have been observed within 30 minutes. This test, therefore, indicates that further reductions in specific torch power are possible.

At 17:40 hours, the feed was shut off and testing discontinued.

## 7. PILOT TEST MATERIAL BALANCES

The overall material balances on solids, water, feed, and glass product have been discussed in Sections 5 and 6. The following section combines the overall stream mass flowrates, processing times, and chemical analyses of the various streams (sediment, filtrate, additives, plasma feed, glass product, offgas, and scrubber water) to generate material balances for each of the analyzed components in the system. Components considered including mineral oxides ( $MO_x$ ), trace hazardous metals (RCRA), total organic carbon (TOC), semivolatile organic compounds (SVOC's), polychlorinated biphenyls (PCB's), dioxins and furans, chloride (Cl), sulfur (S), fixed gases (nitrogen, oxygen, argon, and carbon dioxide), nitrogen oxides ( $NO_x$ ), and sulfur oxides ( $SO_x$ ). Leaching analyses (TCLP) were also performed.

### 7.1 METHODOLOGY

Chemical analyses were obtained from a variety of sources, with most of the analyses confined to material from Test 3. Brookhaven National Laboratory (BNL) and their contract laboratories performed assays on most streams (i.e., TOC, Cl, S, PCB, SVOC, dioxins, furans, and RCRA analyses for the sediment, filter cake, plasma feed, product glass, additives, filtrate water, rinse water, and scrubber water, as well as TCLP for the glass product). BNL subcontracted Affiliated Environmental Services (AES) to collect an offgas sample directly from the plasma melter. Assays for Cl, S, RCRA, PCB, dioxins and furans, and pesticides were performed on the collected gas sample under the BNL quality assurance and quality control protocols. Most gas assays were performed by Triangle Laboratories..

In addition to the Brookhaven analyses, Westinghouse independently performed analyses needed in a timely fashion to make processing decisions and assays not included in the BNL plan that Westinghouse deemed necessary. These assays included:

- Corning Engineering Laboratory Services (CELS): C, Cl, S, and  $MO_x$  analyses of the raw sediments
- Spectrochemical Laboratories: C, Cl, S, and  $MO_x$  analyses of the mixed plasma feed and product glass
- Antech Ltd.: Cl, S, and Na analyses for the scrubber water as a function of time

- K Chem Labs, Inc.: TOC, S, SVOC, and TCLP of the final scrubber water for disposal certification
- Air Quality Services, Inc. (AQS): fixed gases, SO<sub>x</sub>, and NO<sub>x</sub> for the melter offgas
- Westinghouse Science and Technology Center (WSTC): moisture content and electron microscope MO<sub>x</sub> analyses.

Summary sheets including all analyses used in the component material balances from each of the laboratories are included as Appendices A through G.

To generate the component material balances, the analyses described above were first entered into an Excel spreadsheet, and converted to a consistent weight fraction basis. Analyses are presented in a variety of formats, including weight fraction of total stream, weight fraction on a dry basis, weight fraction on a calcined basis, weight per liter (liquid solutions), weight per standard dry volume (gas analyses), and mass flowrates (NO<sub>x</sub> and SO<sub>x</sub>). Using appropriate conversions and known mass flowrates, each was converted to a weight fraction.

An attempt was made to complete material balances for each component over the five major unit operations in the overall process, namely (1) sluicing and dewatering, (2) blending with flux additives, (3) feed partition in material used for the three tests and unused feed, (4) plasma vitrification, and (5) offgas scrubbing. This process required assumptions, since not all components were analyzed in all intermediate streams. Assumptions include the following:

- Metal oxide, RCRA, and toxic organic analyses of the cuttings (oversize screenings) are the same as those for the raw sediment (dry basis). An arbitrary 25% carbon analysis is assumed to account for the high content of vegetable matter, paper, etc. The water content was measured at WSTC.
- The same assumptions are made for the MO<sub>x</sub> analyses of the filter cake, setting these values equal to their counterparts in the raw sediment (dry basis).
- Dilution water used to reduce the solids content of the plasma feed is assumed to be identical to rinse water used in the sluicing and dewatering process.
- Plasma feed processed during Test 1 (Batch B-1) is assumed identical to that processed during the latter half of the Demonstration Test 3 (Batch B-2). Similarly, Test 2 feed (Batch A-1) is assumed identical to material used in the first half of Test 3 (Batch A-2). Adjustment is made for known differences in moisture content, Na<sub>2</sub>CO<sub>3</sub>, and CaO additives. Unused feed material consists primarily of Batch B-1 feed.
- All metal analyses were converted to an elemental basis. This permitted, for example, CaO (mineral oxide analysis), hydrated lime, and slaked lime to be combined into a common calcium content.

- Chloride was assumed to be present as NaCl, and adjustments made in total sodium or Na<sub>2</sub>O analyses accordingly.
- In the case of dioxins, furans, and semivolatile organics, analyses which were reported as estimated maximum concentrations (EMC's) or values below the quantitation and detection limits of the technique were *not included*; they were assumed to be zero. Similarly, analyses which appeared in the blanks were also *not included* in the material balance. Individual analyses for which EMC's were reported by the laboratory or for which the species appeared in the blanks are clearly flagged as such in Appendices A through G.

For each stream, the mass flowrate or total stream mass was developed using the data in Sections 4 through 6. Using the total feed generated during Pretreatment, a partition was made into five substreams, based on actual drum weights processed in each of the three melter tests and weight of the residual feed not vitrified. Partition was therefore made into Test 1 feed, Test 2 feed, unused material, Test 3 Batch A-2 material, and Test 3 Batch B-1 material (the latter two maintained separately since the compositions differed and separate analyses were available). Whereas the overall mass balance around the Pretreatment section included *all* of the sediment delivered by Brookhaven, a detailed material and component balance around the Plasma Vitrification system was carried out only for material processed during Test 3, the test in which the samples were analyzed to provide material balance information.

The total masses of each component were then calculated as the product of the total stream mass and the weight fraction of each component. A total of 434 minutes of plasma system operation occurred during Test 3, and this was used to obtain the total mass of process air and offgas.

Particular attention must be paid to the melter offgas. AES measured a volumetric flowrate for the offgas in the melter offgas ductwork variously at 2400 to 3100 scfm. Input air to the melter through the torch and shroud never exceeded 500 scfm and the charge door was closed at all times during Test 3, so that using the uncorrected AES data leads to a 400% discrepancy in the nitrogen and argon material balances (the two fixed gases which are not involved in chemical reactions). Similar, a very large discrepancy occurs in the water balance around the melter using the AES total flow and moisture analyses. It is known that because of mechanical constraints, it was not possible for AES to install their measurement equipment at a location providing adequate distance from the closest upstream duct elbow; the pitot tube flow measurements used to compute the volumetric flowrates are thus known to be in error.

To generate a reliable material balance around the melter, *the offgas flowrate was scaled down from the AES value to achieve closure on the flow of N<sub>2</sub>, the largest component of the air stream. The required scaling factor was found to be 0.165. Reducing the total mass flow of air by a factor of six increases the concentrations of contaminants reported by the same factor, since the reported concentrations of*

metals and organics were calculated as the measured masses of material collected in the impingers divided by the pitot tube mass flowrate. The exceptions to this methodology are sulfur and nitrogen oxides, which were measured as actual gas-phase concentrations by a fluorescence technique.

A material balance cannot be completed around the scrubber because both inlets (i.e., melter offgas and fresh scrubber water), but only one outlet (final scrubber water) are known. Stack gas flowrate and analysis are not available since analysis of the clean offgas was deferred by BNL due to the cost. Component material balances around the scrubber generate by difference *an implied stack mass flowrate for each species*. This will be a calculated, rather than measured amount. Analysis of the final scrubber water is representative for dissolved species, but it cannot be determined whether suspended solids such as entrained glass or unreacted feed particles are representatively sampled.

## 7.2 COMPONENT ANALYSES

Component analyses derived from Appendices A through G are summarized in Table 7.1 and Table 7.2. Note that the bases of the original laboratory analyses vary, including total stream, dry basis (i.e., total less moisture content), and calcined basis (i.e., total less loss on ignition or LOI). In general most analyses are on a dry solids basis, with the obvious exception of moisture. The only other exceptions involve the metal and sulfur analyses reported by Spectrochemical Laboratories of the plasma feed and product glass, which are on a *calcined solids* basis and must be corrected by the factor  $1/(1-LOI)$ . Solution analyses assume a specific gravity of unity for conversion to weight fraction. Analyses for metals vary on whether they are reported on a metal basis or metal oxide basis. In the tables, mineral species are reported on a metal oxide basis, while toxic heavy metals are converted to elemental basis.

The sediment has been submerged in the Harbor for a long period of time, so that any heavy metals present will be associated with the solids rather than existing as dissolved species. Since filtration involves only removal of water (and dissolved salt), comparison of contaminant analyses between the raw sediment (dry basis) and the filter cake (also dry basis) should yield very similar results. Most of the RCRA metals present values which differ little; analyses for Ni, Cd, Cr, Cu, Pb, Se, Zn, and As all agree within 10% between these two streams. Somewhat larger error (-30% change) is seen for Ag, while Hg actually *increases* by 50%, suggesting inaccuracy in the mercury analysis.

The overall organic analyses are also of interest. The two streams have nearly identical TOC analyses (within 4%), indicating that essentially all of the organic carbon species are bound to the solids and are not removed by filtration. The total sum of semivolatile organics and furans similarly agree quite closely. The dioxin analyses are more difficult to resolve, apparently *increasing* by a factor of 2.5 on a

Table 7.1 Component Analyses for Feed Pretreatment Streams

Component (w/f)	As-Dredged Sediment	Rinse Water	Hydrated Lime	Oversize Cuttings/ Debris	Filtrate Water	Dewatered Filter Cake	Slaked Lime	Soda Ash	Dilution Water	Total Plasma Feed	Test #1 Plasma Feed (B-1)
Air											
Solids	0.371			0.240							0.514
Water	0.629			0.760							0.486
LOI				0.2917						0.1839	0.1839
SiO <sub>2</sub>	0.4905			0.4905		0.4905				0.3834	0.3834
Al <sub>2</sub> O <sub>3</sub>	0.0978			0.0978		0.0978				0.0907	0.0907
Ca (total)	0.0272			0.0272		0.0580	0.7148			0.0925	0.0982
CaO (mineral)	0.0380			0.0380		0.0380				0.0380	0.0360
CaO (lime)							1.00			0.0444	0.0345
Ca(OH) <sub>2</sub>			1.00		0.0017	0.0571				0.0621	0.0857
MgO	0.0199			0.0199		0.0199				0.0180	0.0180
Fe <sub>2</sub> O <sub>3</sub>	0.0576			0.0576		0.0576				0.0613	0.0613
TiO <sub>2</sub>	1.04E-02			1.04E-02	0.0000	1.04E-02				4.82E-03	4.82E-03
K <sub>2</sub> O	0.0205			0.0205		0.0205				0.0155	0.0155
Na (total)	0.0231			0.0231	0.0016	0.0111		0.4340		0.0622	0.0622
Na <sub>2</sub> O	0.0312			0.0312		0.0130				0.0839	0.0839
Na <sub>2</sub> CO <sub>3</sub>								1.00		0.1259	0.0903
NaCl	0.0261			0.0149	0.0040	0.0037				0.0133	0.0145
Cl	0.0159			0.0091	0.0024	0.0022				0.0081	0.0088
S (total)	0.0272			0.0272		0.0272				0.0111	0.0111
SO <sub>3</sub> (mineral)	0.0680			0.0680		0.0680				0.0277	0.0277
SO <sub>2</sub>											
S (sulfide)	0.0079			0.0079		3.70E-06				1.85E-06	1.85E-06
Ag	1.60E-05			1.60E-05		1.34E-05				1.33E-05	1.33E-05
As	3.06E-05		1.68E-06	3.06E-05	1.30E-08	3.89E-05				3.03E-05	3.03E-05
B	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.60E-06	7.60E-06
Ba										2.19E-05	2.19E-05
Be	0.0					0.0					
Cd	3.30E-05			3.30E-05		3.06E-05				2.43E-05	2.43E-05
Cr	3.42E-04		1.99E-06	3.42E-04		3.57E-04	1.45E-05			2.83E-04	2.83E-04
Cu	1.16E-03	5.40E-08	1.68E-06	1.16E-03	1.95E-07	1.02E-03	1.08E-06	5.00E-07	5.40E-08	7.96E-04	7.96E-04
Hg	2.08E-06			2.08E-06	5.00E-09	3.09E-06				2.54E-06	2.54E-06
Mn										3.16E-05	3.16E-05
Ni	2.52E-04	3.00E-09	1.78E-06	2.52E-04	1.30E-07	2.35E-04	1.68E-06		3.00E-09	1.79E-04	1.79E-04
P											
Pb	5.87E-04	3.00E-09		5.87E-04	1.50E-08	6.40E-04			3.00E-09	5.01E-04	5.01E-04
Sb	0.0					0.0					
Se	4.92E-06			4.92E-06	7.90E-08	5.39E-06				3.24E-06	3.24E-06
Sn	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.43E-06	6.43E-06
Sr										1.38E-04	1.38E-04
Tl	0.0				6.00E-09	0.0					
V										2.28E-05	2.28E-05
Zn	1.69E-03	2.40E-08		1.69E-03	1.74E-07	1.68E-03	1.47E-05		2.40E-08	1.35E-03	1.35E-03
Zr											
C	0.0885			0.25	5.10E-05	0.0846		0.1132		0.0870	0.0870
TOC	0.0884			0.25	5.10E-05	0.0846				0.0628	0.0628
PCB	7.00E-06	4.60E-13		7.00E-06	3.44E-12	5.94E-06			4.60E-13	6.14E-06	6.14E-06
SVOC	2.34E-04	1.81E-12		2.34E-04	1.09E-07	2.12E-04			1.81E-12	2.34E-04	2.34E-04
Dioxins	6.55E-09			6.55E-09	7.90E-15	1.66E-08				2.16E-08	2.16E-08
Furans	1.63E-08			1.63E-08		1.62E-08				1.17E-08	1.17E-08
N <sub>2</sub>											
O <sub>2</sub>											
CO <sub>2</sub>											
Ar											
NO <sub>2</sub>											
SO <sub>2</sub>											

Values in italics are computed or assumed from previous analyses; all other values are take directly from lab reports.

Table 7.2 Component Analyses for Plasma Vitrification Streams

Component (w/f)	Test #2 Plasma Feed (A-1)	Unused Feed	Test #3 Plasma Feed (A-2)	Test #3 Plasma Feed (B-1)	Process Air	Glass Product (A-2)	Glass Product (B-1)	Offgas	Scrubber Water (Initial)	Scrubber Water (Final)
Air										
Solids	0.564	0.539	0.453	0.463						
Water	0.436	0.461	0.547	0.537		0.0013	0.0328			
LOI	0.1839	0.1839	0.1850	0.1839						
SiO <sub>2</sub>	0.3834	0.3834	0.3908	0.3834		0.4645	0.4934	0.4790		
Al <sub>2</sub> O <sub>3</sub>	0.0907	0.0907	0.0921	0.0907		0.1686	0.1530	0.1608		
Ca (total)	0.0955	0.1343	0.0641	0.0867		0.0827	0.0963	0.0584		
CaO (mineral)	0.0380	0.0380	0.0897	0.1214		0.1157	0.1347	0.1252		
CaO (lime)	0.0589	0.0889	0.0471	0.0345						
Ca(OH) <sub>2</sub>	0.0486	0.0804	0.0379	0.0857						
MgO	0.0180	0.0180	0.0187	0.0180		0.0223	0.0238	0.0231		
Fe <sub>2</sub> O <sub>3</sub>	0.0613	0.0613	0.0518	0.0613		0.0676	0.0733	0.0705		
TiO <sub>2</sub>	4.82E-03	4.82E-03	5.46E-03	4.82E-03		6.80E-03	7.40E-03			
K <sub>2</sub> O	0.0155	0.0155	0.0172	0.0155		0.0175	0.0199	0.0187		
Na (total)	0.0622	0.0622	0.0877	0.0622		0.0939	0.0600	3.12E-05	2.20E-04	4.90E-04
Na <sub>2</sub> O	0.0839	0.0839	0.1182	0.0839		0.1265	0.0809			
Na <sub>2</sub> CO <sub>3</sub>	0.1485	0.0889	0.1727	0.0903						
NaCl	0.0120	0.0145	0.0120	0.0145		1.65E-04	1.65E-04	1.45E-03	1.81E-03	3.30E-03
Cl	0.0073	0.0088	0.0073	0.0088		1.00E-04	1.00E-04	8.82E-04	1.10E-03	2.00E-03
S (total)	0.0111	0.0111	0.0093	0.0111		9.00E-05	3.80E-04	2.48E-03	1.10E-03	2.30E-03
SO <sub>3</sub> (mineral)	0.0277	0.0277	0.0233	0.0277		2.25E-04	9.50E-04			
SO <sub>2</sub>								4.33E-03		
S (sulfide)	1.85E-06	1.85E-06	1.85E-06	1.85E-06						
Ag	1.33E-05	1.33E-05	1.33E-05	1.33E-05		2.66E-06	2.46E-06	1.19E-07	2.00E-09	3.77E-07
As	3.03E-05	3.03E-05	3.03E-05	3.03E-05		5.29E-06	5.24E-06	2.71E-08		
B	7.60E-06	7.60E-06	7.59E-06	7.60E-06	0.00E+00	9.31E-06	9.31E-06	0.00E+00	0.00E+00	0.00E+00
Ba	2.19E-05	2.19E-05	2.19E-05	2.19E-05		2.69E-05	2.69E-05	1.36E-08		
Be			0.0	0.0		2.02E-06	1.90E-06	0.0		
Cd	2.43E-05	2.43E-05	2.43E-05	2.43E-05		9.46E-07	9.53E-07	1.56E-05	6.00E-09	1.30E-06
Cr	2.83E-04	2.83E-04	2.83E-04	2.83E-04		9.57E-04	1.09E-03	2.91E-05	8.00E-08	2.21E-05
Cu	7.96E-04	7.96E-04	7.96E-04	7.96E-04		1.03E-03	1.18E-03	3.33E-06	1.50E-08	3.13E-06
Hg	2.54E-06	2.54E-06	2.54E-06	2.54E-06		0.0	0.0	1.10E-08		
Mn	3.16E-05	3.16E-05	3.16E-05	3.16E-05		3.87E-05	7.74E-05			
Ni	1.79E-04	1.79E-04	1.79E-04	1.79E-04		2.45E-04	2.90E-04	1.05E-05	4.00E-09	2.83E-07
P						2.23E-03	2.84E-03			
Pb	5.01E-04	5.01E-04	5.01E-04	5.01E-04		1.11E-04	9.20E-05	3.42E-06	2.05E-07	1.40E-05
Sb			0.0	0.0		0.0	0.0	0.0		
Se	3.24E-06	3.24E-06	3.24E-06	3.24E-06		1.53E-06	1.60E-06	6.65E-10		
Sn	6.43E-06	6.43E-06	6.42E-06	6.43E-06	0.00E+00	7.88E-06	7.88E-06	0.00E+00	0.00E+00	0.00E+00
Sr	1.38E-04	1.38E-04	2.07E-04	1.38E-04		4.23E-05	8.46E-05			
Tl			0.0	0.0		5.35E-06	6.17E-06			
V	2.28E-05	2.28E-05	2.28E-05	2.28E-05		2.80E-05	2.80E-05			
Zn	1.35E-03	1.35E-03	1.35E-03	1.35E-03		1.22E-03	1.29E-03	1.00E-04	6.08E-07	5.11E-05
Zr						2.00E-04	2.29E-04			
C	0.0870	0.0870	0.0830	0.0870		1.50E-04	2.50E-04	4.17E-03	1.20E-06	0.0
TOC	0.0628	0.0628	0.0628	0.0628					1.20E-06	6.10E-06
PCB	6.14E-06	6.14E-06	6.14E-06	6.14E-06					2.45E-12	0.0
SVOC	2.34E-04	2.34E-04	2.34E-04	2.34E-04		0.00E+00	0.00E+00	0.00E+00	2.43E-09	1.77E-09
Dioxins	2.16E-08	2.16E-08	2.16E-08	2.16E-08		0.00E+00	0.00E+00	5E-13	0.00E+00	5.99E-12
Furans	1.17E-08	1.17E-08	1.17E-08	1.17E-08		0.00E+00	0.00E+00	7.87E-13	4.40E-15	1.24E-11
N <sub>2</sub>					0.7551			0.8086		
O <sub>2</sub>					0.2315			0.1761		
CO <sub>2</sub>					0.0005			0.0153		
Ar					0.0128			0.0235		
NO <sub>2</sub>								2.88E-03		
SO <sub>2</sub>								4.33E-03		

Values in italics are computed or assumed from previous analyses; all other values are take directly from lab reports.

dry solids basis during the filtration process. A further increase of 30% appears to occur during feed blending. Neither of these analyses can be readily explained and must result from a combination of analytical error and sampling nonuniformities, underscoring the difficulty of accurate analysis of these compounds at such low concentrations. Analyses of these important compounds are discussed further later in this chapter.

Sulfur exists in at least two forms, with reactive sulfide comprising 29% of total sulfur in the as-dredged sediment. Most of the sulfide appears to be water soluble, with the sediment indicating 0.79% sulfide and the filter cake only exhibiting a 3.7 ppm sulfide content. This result may indicate that most of the sulfide present is dissolved  $H_2S$  trapped in the sediment, which is readily released and rinsed out during filtration. The balance of total sulfur is probably a mixture of non-reactive organosulfur compounds and mineral sulfates. Sodium sulfate is also known to be a component of seawater, but is typically present at only about 900 ppm sulfur basis. Sodium sulfate, therefore, cannot account for more than a small fraction of the sediment sulfur.

It is notable that filtration of the sediment not only eliminates 99.9% of the reactive sulfide but also decreases the total sulfur by about 60% (comparing as-dredged sediment to plasma feed; no total sulfur analysis was performed by BNL for the filter cake). The TOC does not decrease significantly, so that the loss in sulfur cannot be attributed to soluble organosulfur species. Sulfur behavior is discussed further later in this chapter.

### 7.3 COMPONENT MASS THROUGHPUTS

Component throughputs (kilograms processed) are shown Table 7.3 and Table 7.4. As indicated above, these values represent the products of the weight fractions of each analyzed component and the stream mass throughput. Total stream throughputs for the Pretreatment segment of the process are taken from Figure 5.8. Mass flowrates for the Vitrification segment are derived variously from logs of feed drum weights before and after feeding, water additions and flow measurements, air flowmeter data, and weights of mold boxes and sample containers following the test. Note again that detailed material balancing around the Vitrification segment is possible only for Test 3; feed consumed during Tests 1 and 2 and unused feed appears in the tables, but is not used in determining material balances around the melter.

Figure 7.1 shows a graphical summary of the major component material balance for each principal stream and unit operation in the total process. Shown are the net throughputs of solids, water, mineral oxides, organics, chloride, RCRA metals, air, and gases, as well as the total stream mass flowrates.

Taking the sums of streams in and out of each unit operation yields the results shown in Table 7.5. This table represents the degree of closure of the material

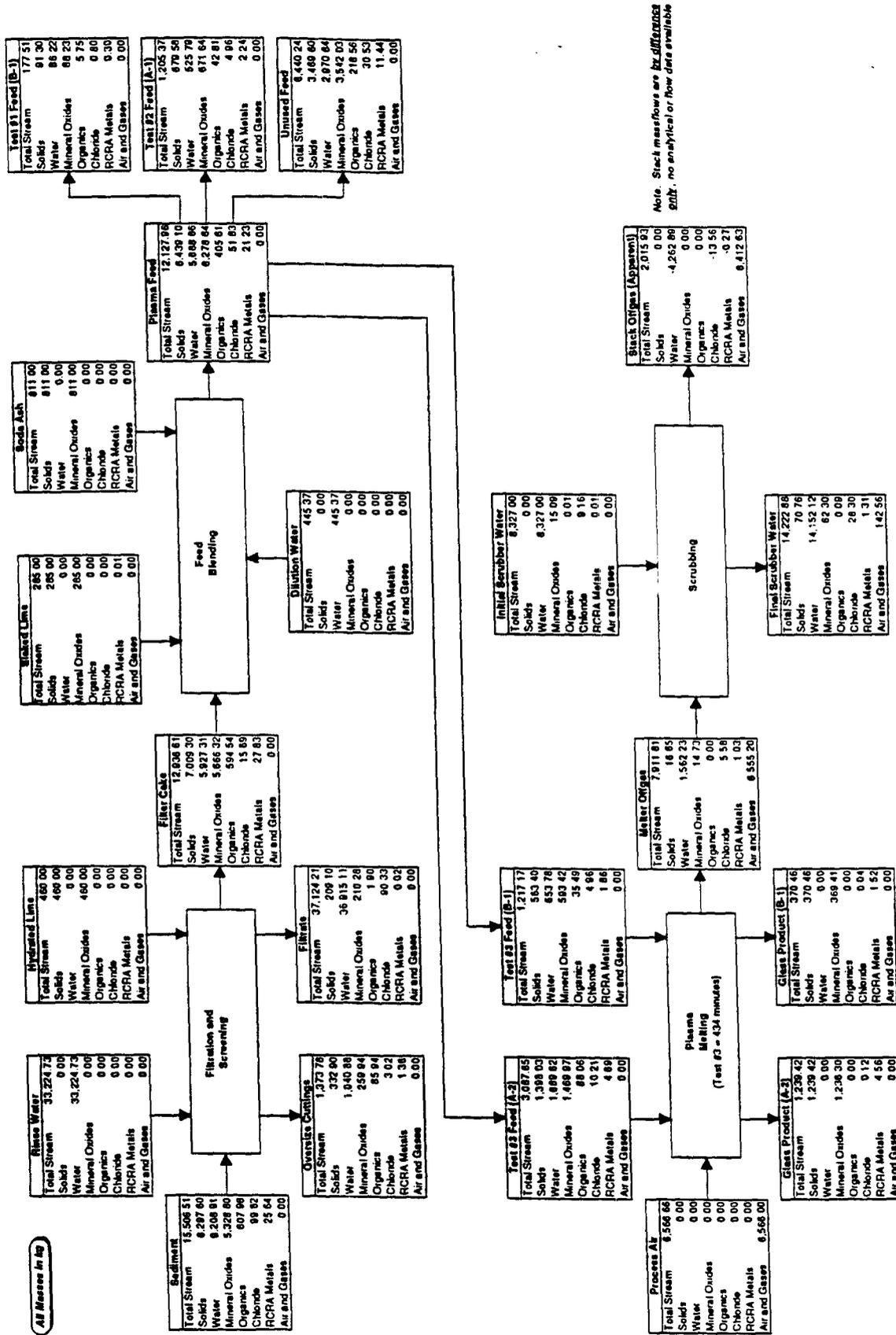
**Table 7.3 Component Throughputs for Pretreatment Streams**

Component (kg)	Sediment	Rinse Water	Hydrated Lime	Oversize Cuttings	Filtrate	Filter Cake	Slaked Lime	Soda Ash	Dilution Water	Total Plasma Feed	Test #1 Plasma Feed (B-1)
Total Stream	15,506.51	33,224.73	460.00	1,373.78	37,124.21	12,936.61	285.00	811.00	445.37	12,127.96	177.51
Air											
Solids	6,297.60		460.00	332.90	209.10	7,009.30	285.00	811.00		6,439.10	91.30
Water	9,208.91	33,224.73		1,040.88	36,915.11	5,927.31			445.37	5,688.86	86.22
Si	1441.52			76.20		1604.43				1,152.14	16.34
Al	326.07			17.24		362.92				309.10	4.38
Ca (total)	171.06		248.93	9.04	0.19	406.85	203.72			595.81	8.97
CaO (mineral)	239.31			12.65		266.35				286.03	3.15
CaO (lime)							285.00			285.00	4.04
Ca(OH) <sub>2</sub>			460.00		61.35	400.00				398.65	5.65
Mg	75.57			3.99		84.11				70.03	0.99
Fe	253.43			13.40		282.07				275.97	3.91
K	107.17			5.67		119.28				82.89	1.18
Ti	97.0032			8.5938		80.9268				35.0096	0.5124
Na (total)	145.83			9.66	58.61	77.56		351.94		400.81	5.68
Na <sub>2</sub> O	109.32			10.39		90.82				540.23	7.66
Na <sub>2</sub> CO <sub>3</sub>								811.00		811.00	11.50
NaCl	164.49			4.97	148.94	25.87				85.42	1.32
Cl	99.82			3.02	90.33	15.69				51.83	0.80
S (total)	171.29			9.05	90.97	71.27				71.27	1.01
S (sulfide)	49.75			2.63		0.03				0.01	0.00
Ag	0.1008			0.0053		0.0939				0.0856	0.0012
As	0.1927		0.0008	0.0102	0.0005	0.2727				0.1948	0.0028
B										0.0399	0.0006
Ba										0.1412	0.0020
Be	0.0000					0.0000				0.0000	0.0000
Cd	0.2078			0.0110		0.2145				0.1561	0.0022
Cr	2.1538		0.0009	0.1139		2.5023	0.0041			1.8190	0.0258
Cu	7.3052	0.0018	0.0008	0.3862	0.0072	7.1495	0.0003	0.0004	0.0000	5.1255	0.0727
Hg	0.0131			0.0007	0.0002	0.0217				0.0163	0.0002
Mn										0.1661	0.0024
Ni	1.5870	0.0001	0.0008	0.0839	0.0048	1.6472	0.0005		0.0000	1.1494	0.0163
P											
Pb	3.6967	0.0001		0.1954	0.0006	4.4860			0.0000	3.2228	0.0457
Sb	0.0000					0.0000				0.0000	0.0000
Se	0.0310			0.0016	0.0029	0.0378				0.0208	0.0003
Sn										0.0338	0.0005
Sr										0.7253	0.0103
Tl	0.0000				0.0002	0.0000				0.0000	0.0000
V										0.1201	0.0017
Zn	10.6429			0.5626	0.0065	11.7756	0.0042			8.6606	0.1228
Zr											
C (total)	557.34			83.23	1.88	501.45		91.81		560.20	7.94
TOC	556.71			83.23	1.89	592.99				404.05	5.73
PCB	0.0441	1.53E-08		0.0023	1.28E-07	0.0416			2.05E-10	0.0396	0.0006
SVOC	1.4739	6.01E-08		0.0779	4.04E-03	1.4873			8.06E-10	1.5047	0.0213
Dioxins	4.12E-05			2.18E-06	2.93E-10	1.16E-04				1.39E-04	1.98E-06
Furans	1.03E-04			5.43E-06		1.13E-04				7.52E-05	1.07E-06
N <sub>2</sub>											
O <sub>2</sub>											
CO <sub>2</sub>											
Ar											
NO <sub>2</sub>											
SO <sub>2</sub>											

Table 7.4 Component Throughputs for Plasma Vitrification Streams

Component (kg)	Test #2 Plasma Feed (A-1)	Test #3 Unused Feed (A-2)	Test #3 Plasma Feed (A-2)	Test #3 Plasma Feed (B-1)	Process Air	Glass Product (A-2)	Glass Product (B-1)	Melter Offgas	Scrubber Water (Initial)	Scrubber Water (Final)
Total Stream	1205.37	6440.24	3087.65	1217.17	6566.659	1239.42	370.46	7911.81	8327.00	14222.88
Air					6566.659			6332.93		
Solids	679.58	3469.60	1398.03	563.40		1239.42	370.46	16.65		70.76
Water	525.79	2970.64	1689.62	653.78				1562.23	8327.00	14152.12
Si	121.60	620.81	254.97	100.81		268.66	85.30	3.72		15.82
Al	32.62	166.55	68.17	27.04		110.63	30.01	1.25		5.31
Ca (total)	64.92	465.88	89.59	48.87		102.50	35.67	0.97		4.13
CaO (mineral)	40.00	308.61	125.34	68.37		143.40	49.90	2.08		8.86
CaO (lime)	30.08	153.57	61.88	24.94						
Ca(OH) <sub>2</sub>	42.07	214.81	86.55	34.88						
Mg	7.39	37.73	15.80	6.13		16.67	5.32	0.18		0.76
Fe	29.13	148.70	50.67	24.15		58.59	18.99	0.55		2.33
K	8.75	44.66	19.96	7.25		18.01	6.12	0.15		0.62
Ti	3.4795	18.5910	10.1083	3.5136		5.0526	1.6435	0.0019		
Na (total)	42.30	215.97	122.58	35.07		116.33	22.24	0.20	1.83	6.93
Na <sub>2</sub> O	57.02	291.09	165.22	47.27		156.79	29.97			
Na <sub>2</sub> CO <sub>3</sub>	85.59	436.99	176.08	70.96						
NaCl	8.18	50.31	16.82	8.17		0.20	0.06	0.02	15.09	0.23
Cl	4.96	30.53	10.21	4.96		0.12	0.04	5.58	9.16	28.30
S (total)	7.52	38.40	13.04	6.24		0.11	0.14	13.76	9.16	32.55
S (sulfide)	0.0013	0.0064	0.0026	0.0010		0.00	0.00	0.00	0.00	0.00
Ag	0.0090	0.0461	0.0186	0.0075		0.0033	0.0009	0.0008	0.0000	0.0053
As	0.0206	0.1050	0.0423	0.0170		0.0066	0.0019	0.0002	0.0000	0.0112
B	0.0042	0.0215	0.0086	0.0035		0.0115	0.0034			
Ba	0.0149	0.0761	0.0306	0.0124		0.0333	0.0100	0.0000		0.0001
Be	0.0000	0.0000	0.0000	0.0000		0.0025	0.0007			
Cd	0.0165	0.0841	0.0339	0.0137		0.0012	0.0004	0.0991	0.0000	0.0184
Cr	0.1920	0.9802	0.3949	0.1592		1.1855	0.4038	0.1842	0.0007	0.3128
Cu	0.5409	2.7618	1.1128	0.4485		1.2704	0.4371	0.0211	0.0001	0.0443
Hg	0.0017	0.0088	0.0035	0.0014				6.97E-05		1.56E-05
Mn	0.0175	0.0895	0.0360	0.0145		0.0480	0.0287			
Ni	0.1213	0.6193	0.2495	0.1006		0.3037	0.1074	0.0665	0.0000	0.0040
P						2.7599	1.0514			
Pb	0.3401	1.7365	0.6997	0.2820		0.1376	0.0341	0.0217	0.0017	0.1981
Sb	0.0000	0.0000	0.0000	0.0000						0.0025
Se	0.0022	0.0112	0.0045	0.0018		0.0019	0.0006	4.21E-06		0.0013
Sn	0.0036	0.0182	0.0073	0.0030		0.0098	0.0029			
Sr	0.0765	0.3908	0.2356	0.0635		0.0524	0.0313			
Tl	0.0000	0.0000	0.0000	0.0000		0.0066	0.0023			0.0009
V	0.0127	0.0647	0.0260	0.0105		0.0347	0.0104			
Zn	0.9140	4.6666	1.8804	0.7578		1.5059	0.4779	0.6356	0.0051	0.7232
Zr						0.2477	0.0850			
C (total)	59.12	301.86	116.04	49.02		0.19	0.09	26.43		0.00
TOC	42.64	217.72	87.73	35.35					0.01	0.09
PCB	0.0042	0.0213	0.0086	0.0035		0.00	0.00	0.00	2.04E-08	0.00
SVOC	0.1588	0.8108	0.3267	0.1317		0.00E+00	0.00E+00	0.00E+00	2.02E-05	2.50E-05
Dioxins	1.47E-05	7.51E-05	3.03E-05	1.22E-05		0.00E+00	0.00E+00	3.17E-09		8.48E-08
Furans	7.94E-06	4.05E-05	1.63E-05	6.58E-06		0.00E+00	0.00E+00	4.98E-09	3.66E-11	1.75E-07
N <sub>2</sub>					4958.48			5120.81		
O <sub>2</sub>					1520.18			1115.23		
CO <sub>2</sub>					3.28			96.89		96.89
Ar					84.05			148.82		
NO <sub>2</sub>								18.23	0.00	18.23
SO <sub>2</sub>								27.44	0.00	27.44

Figure 7.1 Summary Material Balance for Phase II Pilot Tests



**Table 7.5 Material Balance Closure Over Unit Operations**

In (kg)	Overall		Filter Press		Blender		Feed Partition		Plasma Melter		Scrubber	
	Sediment, Water, Lime and Soda Ash, Process Air		Sediment, Rinse Water, Hydrated Lime		Filter Cake, Hydrated Lime, Soda Ash, Dilution Water		Plasma Feed		Test #3(A-2), Test #3(B-1), Process Air		Offgas (Adjusted), Initial Water	
Out (kg)	Filtrate, Oversize Cuttings, Glass, Scrubber Water, Stack Offgas		Filter Cake, Filtrate, Oversize Cuttings		Plasma Feed		Test #1(B-1), Test #2 (A-1), Test #3(A-2), Test #3(B-1), Unused Feed		Glass (A-2), Glass (B-1), Offgas (Adjusted)		Final Water, Stack (By Difference Only; No Data)	
	$\Delta M(kg)$	$\Delta M(w/o)$	$\Delta M(kg)$	$\Delta M(w/o)$	$\Delta M(kg)$	$\Delta M(w/o)$	$\Delta M(kg)$	$\Delta M(w/o)$	$\Delta M(kg)$	$\Delta M(w/o)$	$\Delta M(kg)**$	$\Delta M(w/o)**$
Total Stream	-1,456.47	-2.22%	2,243.36	4.56%	-2,350.03	-16.23%	0.00	0.00%	-1,349.79	-12.42%	-2,015.93	-12.41%
Air	-233.73	-3.56%							-233.73	-3.56%	-6,332.93	-100.00%
Solids	-1,444.59	-18.39%	793.70	11.75%	-1,666.20	-20.56%	-237.19	-3.68%	-334.90	-17.07%	54.11	325.00%
Water	221.84	0.43%	1,449.66	3.42%	-683.83	-10.73%	237.19	4.17%	-781.17	-33.33%	4,262.89	43.11%
Si	-248.89	-17.27%	239.11	16.59%	-452.29	-28.19%	-37.61	-3.26%	1.90	0.54%	12.09	
Al	36.61	11.23%	54.09	16.59%	-53.82	-14.83%	-10.33	-3.34%	46.67	49.02%	4.06	
Ca	64.43	10.33%	-3.91	-0.93%	-14.75	-2.42%	82.42	13.83%	0.68	0.49%	3.16	
Mg	-3.29	-4.36%	12.53	16.59%	-14.08	-16.74%	-1.98	-2.83%	0.23	1.05%	0.58	
Fe	19.83	7.82%	42.04	16.59%	-6.10	-2.16%	-19.41	-7.03%	3.30	4.41%	1.78	
K	-22.65	-21.13%	17.78	16.59%	-36.40	-30.51%	-1.09	-1.32%	-2.94	-10.81%	0.47	
Ti	-59.1284	-60.96%	-7.4825	-7.71%	-45.9172	-56.74%	1.1952	3.41%	-6.9239	-50.83%	-0.0019	-100.00%
Na	-26.79	-5.36%	0.00	0.00%	-28.69	-6.68%	20.80	5.19%	-18.90	-11.99%	4.91	241.73%
Cl	35.57	32.64%	9.22	9.24%	36.15	230.42%	-0.37	-0.72%	-9.42	-62.11%	13.56	91.97%
S	-10.32	-5.72%	0.00	0.00%	0.00	0.00%	-5.06	-7.10%	-5.26	-27.29%	9.63	42.00%
Ag	-0.0341	-33.81%	-0.0015	-1.50%	-0.0083	-8.82%	-0.0032	-3.68%	-0.0211	-80.97%	0.0046	591.18%
As	-0.0459	-23.71%	0.0899	46.44%	-0.0779	-28.56%	-0.0072	-3.68%	-0.0507	-85.39%	0.0110	6423.40%
B	0.0413				0.0399		-0.0015	-3.74%	0.0028	23.46%		
Ba	0.1363				0.1412		-0.0052	-3.71%	0.0003	0.66%	0.0001	31404.11%
Be	0.0032		0.0000		0.0000		0.0000		0.0032		0.0000	
Cd	0.0066	3.17%	0.0176	8.49%	-0.0583	-27.20%	-0.0058	-3.68%	0.0530	111.49%	-0.0807	-81.44%
Cr	0.9265	42.90%	0.4615	21.42%	-0.6874	-27.43%	-0.0670	-3.68%	1.2195	220.08%	0.1279	69.14%
Cu	-1.8110	-24.78%	0.2351	3.22%	-2.0247	-28.32%	-0.1888	-3.68%	0.1674	10.72%	0.0231	108.52%
Hg	-0.0014	-10.70%	0.0094	72.05%	-0.0053	-24.63%	-0.0006	-3.68%	-0.0049	-98.60%	-0.0001	-77.66%
Mn	0.1860				0.1661		-0.0062	-3.74%	0.0262	51.87%		
Ni	-0.2652	-16.69%	0.1480	9.32%	-0.4983	-30.24%	-0.0423	-3.68%	0.1275	36.40%	-0.0625	-93.98%
P	3.8113								3.8113			
Pb	-1.1851	-32.04%	0.9851	26.65%	-1.2632	-28.16%	-0.1187	-3.68%	-0.7884	-80.31%	0.1748	747.69%
Sb	0.0000		0.0000		0.0000		0.0000		0.0000		0.0025	
Se	-0.0102	-32.93%	0.0114	36.69%	-0.0169	-44.86%	-0.0008	-3.68%	-0.0039	-60.71%	0.0013	31805.20%
Sn	0.0349				0.0338		-0.0013	-3.74%	0.0024	23.46%		
Sr	0.5614				0.7253		0.0514	7.09%	-0.2153	-72.00%		
SrO	0.6639		0.0000		0.8578		0.0608	7.09%	-0.2547	-72.00%	0.0000	
Tl	0.0091		0.0002		0.0000		0.0000		0.0089		0.0009	
V	0.1242				0.1201		-0.0045	-3.74%	0.0086	23.46%		
Zn	-1.7552	-16.48%	1.7017	15.99%	-3.1192	-26.48%	-0.3190	-3.68%	-0.0187	-0.71%	0.0825	12.88%
Zr	0.3327								0.3327			
C	-168.42	-25.94%	29.22	5.24%	-33.06	-5.57%	-26.23	-4.68%	-138.35	-83.82%	-26.43	-100.00%
TOC	-205.50	-36.91%	121.40	21.81%	-188.93	-31.86%	-14.88	-3.68%	-123.08	-100.00%	7.63E-02	763.94%
PCB	-1.57E-02	-35.58%	-1.14E-04	-0.26%	-2.06E-03	-4.94%	-1.46E-03	-3.68%	-1.21E-02	-100.00%	-2.04E-08	-100.00%
SVOC	-4.01E-01	-27.21%	9.54E-02	6.47%	1.74E-02	1.17%	-5.54E-02	-3.68%	-4.58E-01	-100.00%	4.81E-06	23.79%
Dioxins	5.27E-05	127.77%	7.73E-05	187.44%	2.30E-05	19.73%	-5.13E-06	-3.68%	-4.24E-05	-99.993%	8.16E-08	2575.05%
Furans	-4.77E-05	-46.48%	1.60E-05	15.56%	-3.81E-05	-33.59%	-2.77E-06	-3.68%	-2.29E-05	-99.978%	1.70E-07	3386.85%
N <sub>2</sub>	162.33	3.27%							162.33	3.27%	-5,120.81	-100.00%
O <sub>2</sub>	-404.95	-26.64%							-404.95	-26.64%	-1,115.23	-100.00%
CO <sub>2</sub>	93.61	2851.09%							93.61	2851.09%	0.00	0.00%
Ar	64.77	77.06%							64.77	77.06%	-148.82	-100.00%
NO <sub>2</sub>	18.23								18.23		0.00	0.00%
SO <sub>2</sub>	27.44								27.44		0.00	0.00%

balance over each of the chemical species in the system, as well as the total streams. For each species the net change in mass (i.e., mass out minus mass in) over the unit operation is presented, along with the percent change; the first column represents the overall material balance (i.e., the sum of all exit streams minus sum of all feed streams).

### 7.3.1 Overall Material Balance Closure

Table 7.5 shows that the closure of the total material balance is very good, within -2.2% overall. Closure on the total throughput of water is even better at +0.43%. The closure on solids indicates an *apparent* disappearance of 1444 kg (-18.39%). This is in part due to destruction of the organic content of the sediment (165 kg of TOC plus 28 kg of associated hydrogen, assuming  $C_nH_{2n+2}$  to represent the hydrocarbon content), dehydration of the calcium hydroxide (30 kg of  $H_2O$ ), and calcination of sodium carbonate to sodium oxide (103 kg of  $CO_2$ ). In addition, Phase I analysis of the sediment mineralogy also indicated that waters of hydration typically make up 0.9% of the sediment on a dry basis, or 18 kg  $H_2O$ . The expected loss of weight of the solids component due to calcination is therefore 344 kg. This value represents 17.5% of the Test 3 plasma feed, in good agreement with the measured loss on ignition (LOI) analysis of 18.5% for the plasma feed.

The bulk of the unaccounted-for solids ( $1444-344 = 1100$  kg, or 14.0%) occurs during the blending operation, where a discrepancy of -1666 kg is observed. This large error is directly attributable to measurement of the moisture content of the various sediment and blend streams. Obtaining consistent and reproducible moisture and solids analysis was found to be very difficult. Representative sampling for solids content is difficult, since the surface of the sediment dries relatively rapidly on contact with air. Solids analysis can be performed consistently when the analysis is done at conditions that lose not only water, but also semivolatile organics.

As indicated above, the overall material balance on process gases closes to within -3.6% when the corrections are made to offgas airflow to balance nitrogen around the melter. Despite the reasonably good closure for gases as a whole, the argon analysis is not particularly good, +77.1% overall. Oxygen exhibits a -26.6% closure (-405 kg), but this may be largely accounted for by assuming stoichiometric reaction of 123 kg of TOC carbon to form  $CO_2$  and hydrogen, representing TOC organics as  $C_nH_{2n+2}$ . This consumes 332kg of oxygen. The oxygen balance, therefore, supports the required adjustment in the AES total offgas flowrate described in Section 7.1.

### 7.3.2 Metal Oxide Uptake from Refractory

The largest chemical component in the sediment is  $SiO_2$ , for which the material balance closure is -17.3%. Missing silica (given the reasonably good overall solids closure) is probably due to analytical error. Analysis of minerals and glass typically

does not sum to unity, and silica is among the most difficult  $MO_x$  species to quantify accurately. Aluminum and iron are the next most common species. Aluminum increases overall by 11.2%, with iron increasing by 7.8%. No unaccounted-for source of iron is known, so that the error is again probably analytical. Closure for magnesium and calcium are -4.4% and +10.3%, respectively, again reflective of accumulated errors in both mass flowrates and analyses.

Glass absorption of refractory oxides is responsible for the increase in alumina content. It was observed that the molten glass dissolved alumina from the tuyere refractory; most of the discrepancy in the material balance over aluminum occurs in the plasma vitrification operation (+49.0%). A second species derived from the refractory is phosphorus, for which 3.8 kg appears during the vitrification process;  $P_2O_5$  is used as a binder in the plastic refractory used in the melter shaft.

### **7.3.3 Alkali Metal Retention in Glass Product**

Sodium and potassium are both susceptible to volatilization in the plasma melter, we predict up to 20% loss of sodium to the offgas. Table 7.4 indicates that of the 158 kg of Na provided in the Test 3 feed, only 5.1 kg reported to the scrubber (of which 0.2 kg was analyzed in the offgas), and 138 kg was accounted for in the glass; the overall material balance closure around the melting operation was reasonably good at -18.9 kg (-12.0%).

Based on the glass analysis, 87% of the sodium fed to the melter reported to the glass product. It is known that analysis of Na in a glass matrix is also very difficult, so that this value is probably conservatively low. Sodium is easy to determine in water; the presence of only 5.1 kg of Na in the scrubber water would imply greater than 97% retention in the product.

Potassium retention was also good, in excess of 88% based on glass analysis. Retention based on scrubber accumulation (believed to be the more accurate assessment) is 98%. The offgas K analysis (0.15 kg) once again is very low as compared with that found in the scrubber (0.62 kg).

### **7.3.4 Solids Entrainment**

Entrainment of some solids into the offgas is expected, although the low superficial velocities in the melter shaft (only 7 ft/sec) would be expected to suspend relatively little material as dense as glass. Total suspended solids (TSS) analysis of the final scrubber water indicates 0.5% total solids, equivalent to only 71.1 kg of solids reporting to the scrubber out of a total of 1609 kg of glass produced during Test 3; this corresponds to a fractional entrainment of 4.4%. This entrainment was produced by an average air flowrate of 450 scfm to the torch and shroud, which was reduced to below 350 scfm during the last hour of the test with no adverse effects. It is believed from this observation that further reduction in air flow is achievable, with corresponding reduction in superficial velocity and particle entrainment.

### 7.3.5 Behavior of Sulfur

The material balance on sulfur is difficult to reconcile. Initial sediment analysis indicates 2.7% total sulfur and 0.8% sulfide, with the latter species eliminated almost totally during filtration (99.94% removal). Blending appears to result in a 62% loss of total sulfur, which can only be attributable to analytical error.

The sulfur balance around the melter is considerably better. Some 73% of the sulfur reported to enter the plasma melter is accounted for, with only 100 to 400 ppm of sulfur analyzed in the product glass (0.25 kg) and 27.4 kg of sulfur leaving in the offgas as 4300 ppm of SO<sub>2</sub>. The balance of the 5.3 kg of sulfur in the plasma feed is unaccounted for. A total of 9.6 kg of sulfur accumulates in the scrubber, however, which must have been transported by the offgas.

Note that this sulfur is not necessarily all sulfur dioxide. At melter temperatures sodium sulfate is a thermodynamically favored species, which is somewhat volatile; a substantial fraction of sulfur loss may therefore occur as sulfate vapor, which would not appear in the SO<sub>2</sub> analysis but would contribute to the scrubber sulfur inventory. This hypothesis is supported by the data in Figure 7.2, which shows sulfur accumulation in the scrubber. During the last 90 minutes of the test when the shroud gas was reduced and the melt temperature increased, the rate of sulfur accumulation in the scrubber also increased, consistent with a transport mechanism involving a semivolatile salt species.

It is also notable that so little offgas sulfur dioxide is observed. It was anticipated that essentially all of the feed sulfur would report as offgas SO<sub>2</sub>, whereas a large fraction of the total sulfur is removed prior to plasma vitrification, and additional sulfur apparently reports as sodium sulfate in the melter. Depending on the efficiency of the scrubber for sulfur dioxide removal, the need for a separate dry sulfur removal process may be reevaluated.

### 7.3.6 RCRA Metals

Material balance closure on the various RCRA metals is typically between  $\pm 5\%$  and  $\pm 30\%$ , with most of the values being negative (material unaccounted for, or MUF). For example, overall closure for Cd is +3.2%, for Hg -10.7%, for Zn -16.5%, for As -23.7%, for Cu -24.8%, and for Pb -32.1%. Discrepancies in overall material balances are again probably simply the sum of multiple massflow and analytical errors rather than anything more systematic. The only stream which could systematically account for loss of a RCRA metal species would be the stack, assuming some of the metal entrained or volatilized in the melter was not recovered in the scrubbing system. Cadmium, however, is among the more volatile of the heavy metals, and shows no missing mass, implying that the scrubber is, as expected, efficiently removing heavy metal vapors and particles from the offgas.

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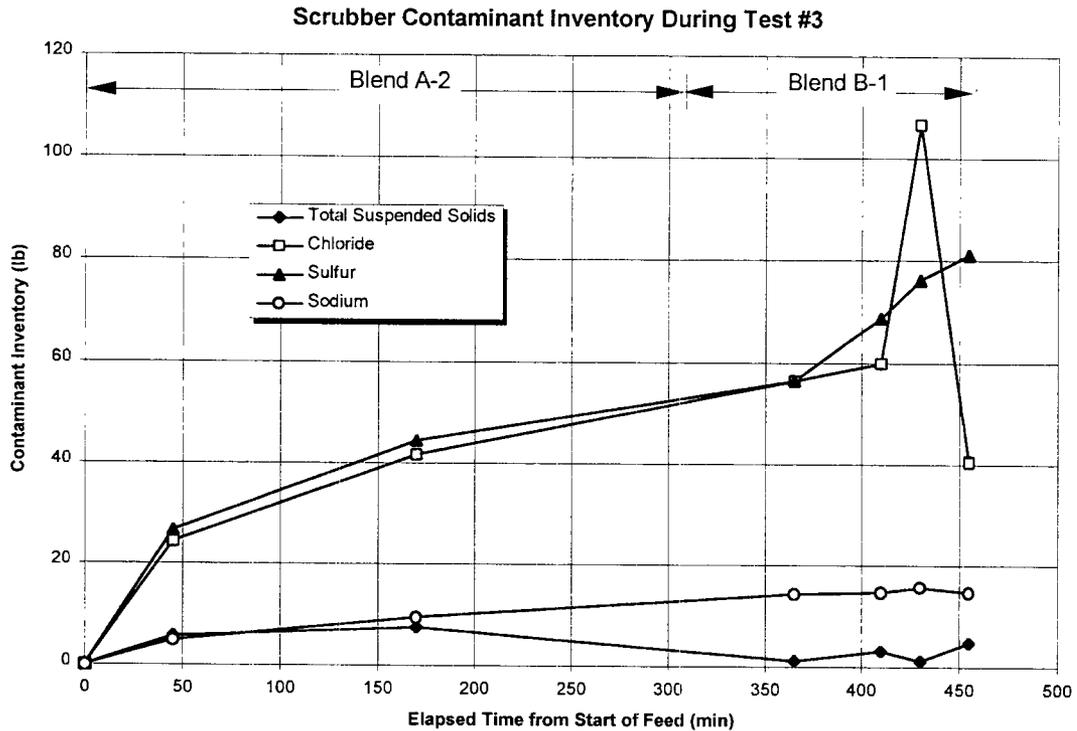


Figure 7.2 Scrubber Accumulation of Sulfur, Chlorine, and Sodium

Material balances around the plasma melter itself (which should characterize the quantity leaving with the offgas) are much more erratic, and show no systematic loss of most of the above metals. Overall closures are observed for Cd of +111%, for Hg -98%, for Zn -1%, for As -85%, for Cu+11%, and for Pb-80%.

A comparison of the total kilograms of each metal in the Test 3 plasma feed compared to the quantity recovered from the scrubber water and the glass appears to be the most accurate way to determine the retention factor in the melt. The "fraction retained" determined by assuming that any material found in the feed but not found in the scrubber reported to the glass. Difficulties in representative sampling and analytical techniques for low level metals in glass make the scrubber water analysis the appropriate choice for calculation. These data are shown in Table 7.6. The "fraction unaccounted for" is the missing metal mass based on the actual glass analysis (Feed - Glass - Scrubber Water), divided by the feed metal mass.

selenium, and 44% of the chromium. Other species are less well solubilized in the glass matrix, including silver and arsenic (20% retention).

**Table 7.6 Retention of RCRA Metals in Glass Product  
(Glass Retention Calculated from Scrubber Accumulation)**

Species	kg in Plasma Feed	kg in Glass Product	kg Reported in Offgas	kg in Final Scrubber Water	Fraction Retained in Glass	Fraction Unaccounted For	Average ppm in Glass
Ag	0.0261	0.0042	0.0008	0.0053	79.7%	63.6%	2.6
As	0.0593	0.0085	0.0002	0.0112	81.1%	66.8%	5.3
Ba	0.0430	0.0433	0.0000	0.0001	99.8%	0.0%	26.9
Cd	0.0476	0.0016	0.0991	0.0184	61.3%	58.0%	1.0
Cr	0.5541	1.5893	0.1842	0.3128	43.5%	-243.3%	987.8
Cu	1.5613	1.7075	0.0211	0.0443	97.2%	-12.2%	1061.2
Hg	0.0049	0.0000	0.000,070	0.000,016	99.7%	99.7%	N/D
Ni	0.3501	0.4111	0.0665	0.0040	98.9%	-18.6%	255.5
Pb	0.9817	0.1717	0.0217	0.1981	79.8%	62.3%	106.7
Se	0.0063	0.0025	0.000,004	0.0013	79.4%	39.7%	1.6
Tl	0.0000	0.0089	0.0000	0.0009	n/a	n/a	5.7
Zn	2.6382	1.9838	0.6356	0.7232	72.62%	-2.6%	1232.9

Although the retention of mercury computed in this way is very high, the analysis is not reliable since Hg would be scrubbed as metallic microdroplets, and sampling inhomogeneities are expected to be a serious problem. Neither is it possible to accurately measure parts per million quantities of Hg in glass. Very low retention is anticipated for mercury in molten glass.

Note that again these numbers must be viewed with the realization that the analyses do not permit closure of the component material balances. Examination of the table indicates that those metals present in the glass at the highest concentrations are those for which the material unaccounted for (MUF) is negligible. All metals having MUF greater than zero with the exception of Zn are present at 100 ppm or less (Hg, Cd, Ag, As, Se, and Pb); all metals except Zn present at greater than 100 ppm have no MUF (Ni, Cu, and Cr). Measurement of trace quantities of metals in a glass matrix is known to be a difficult analytical task; Corning Engineering Laboratory Services routinely carries out glass analyses and has a reputation for being the most reliable source of such data; CELS quotes the detection limit for Ag, Cu, Cr and Pb as 10 ppm, Sb and Ba as 100 ppm, Zn as 300 ppm, and As and Cd as 1000 ppm. All of the low concentration RCRA metals (Cd,

Ag, As, Se, and Ba) are all present below the CELS detection limit. It is not known whether the techniques used by BNL are comparable to the CELS methods, but it is clear that analysis at these low concentrations in glass is very difficult.

Non-closure due to analytical error is further suggested by comparison of the scrubber water and offgas metal masses. All material entering the scrubber had to have come from the offgas, yet in almost half the cases (Ag, As, Pb, and Se) the metal mass in the scrubber *exceeds that in the offgas*. For other metals, the offgas throughput is two to three times that in the scrubber (Cr, Cu, and Zn). In fact, two metals (Cd and Ni) offgas throughputs are reportedly 21 and 66 times that in the scrubber. Scrubber efficiency will not vary drastically from one species to the next.

To try to better understand the partition of these metals between glass, offgas, and scrubber water solution or particulates in the absence of reliable analytical data, thermodynamic simulations were carried out to determine the probably chemical speciation of each of the RCRA metals. The following conclusions were arrived at:

- Zinc is predicted to exist as vapor phase ZnO at temperatures above 1050°C, condensing to solid oxide below this point. Zinc oxide is water-insoluble, and would therefore report to the scrubber as finely divided particulates.
- Copper remains as vapor phase salts above 1200°C, condensing gradually until it is fully solid at 900°C. The final copper species include insoluble Cu<sub>2</sub>O and soluble CuCl, so that copper will exist both as dissolved salt and particulates in the scrubber.
- Cadmium will exist as vapor-phase CdO throughout the melter duct and offgas shaft down to temperatures below 700°C, and should condense only in the scrubber as insoluble CdO particulates.
- Mercury will exist primarily as metal vapor, with some conversion to HgO vapor. Condensation in the scrubber should result in metal particulates (droplets).
- Lead remains in the vapor phase down to 950°C, gradually condensing between 950 and 750°C to insoluble, solid PbO.
- Arsenic should exist as vapor phase AsO down to 900°C, condensing and oxidizing to solid As<sub>2</sub>O<sub>3</sub> between 900 and 750°C.
- Sulfur is *not* predicted to exist as SO<sub>2</sub> gas (consistent with low sulfur dioxide concentrations measured in the offgas), but rather as Na<sub>2</sub>SO<sub>4</sub>. Although generally thought of as a solid, sodium sulfate exhibits significant volatility above 1100°C, and Na<sub>2</sub>SO<sub>4</sub> vapor is predicted to be the major sulfur species above 1300°C. Sulfate would condense below 850°C, and form water-soluble particulates in the offgas duct.

The final conclusion of the thermodynamic simulations is that most of the volatile RCRA metals are predicted to condense as water-insoluble particulates. These particulates will be easily removed in commercial gas cleaning equipment.

Particles should be largely removed from the Pilot Plant offgas by the venturi scrubber, although the efficiency of the scrubber for very fine particles is not well characterized. The Pilot Plant does not contain a dedicated secondary system such as an electrostatic precipitator for final removal of fine particulates. Representative analysis of such particles as are removed from the offgas may be difficult, in that the scrubber recirculation tank permits accumulation of settled solids in a deep well. The analytical samples may therefore not contain representative TSS, nor is it guaranteed that the suspended solids in the sample are analyzed in a representative manner; this factor may account in part for the missing RCRA metals.

In conclusion, determining accurate retention and offgas loadings for RCRA metals is difficult because of a combination of analytical errors and problems in sample representability. Offgas and scrubber water throughputs are not internally consistent, with scrubber data possibly compromised by nonrepresentative sampling of suspended particulates, and offgas data compromised by nonrepresentative sampling of the gas flow stream. Analysis of low concentration metals in glass is also recognized to be very difficult, with several of the important RCRA metals present at close to or below detection limits using the CELS analytical techniques.

### 7.3.7 Organic Species

Good closure is observed for carbon in each of the filtration, blending, and feed partition operations (all within 5%). Closure over the plasma melter is poor (-84%) based on the offgas CO<sub>2</sub> analysis. As discussed previously, excellent closure of the oxygen material balance is obtained if the total carbon is converted to CO<sub>2</sub>, although the AES analysis is low by a factor of six to provide that quantity of carbon dioxide. When the total AES mass flowrate was adjusted downward by 0.165 to balance nitrogen, RCRA metal and organic concentrations were adjusted upward accordingly, but no changes were made in the fixed gas analyses. If CO<sub>2</sub> analysis depends on absorption of a measured quantity of carbon dioxide and then division by the total gas flowrate to obtain the concentration, the CO<sub>2</sub> concentration would increase by a factor of 6.1, almost precisely the factor needed to balance the total carbon throughput.

Semivolatile organics (SVOC's) show good material balance closure over the first three operations (-3 to +6%). The offgases had no reported semivolatiles that are not flagged data, data with blank contamination or values that were below quantitation limits. There is no reason to expect that any semivolatiles will survive plasma temperatures. SVOC destruction is indicated to be, as expected, 100%.

As indicated above, the concentration of dioxin reported in the sediment, filter cake, and plasma feed steadily increases to 3.4 times the feed concentration on a constant dry weight basis, indicating analytical error or sample variability is

substantial. Overall closure on dioxin is positive (+128%), although this is well within the scatter apparent in analysis over the first three unit operations. At least 99.99% destruction of dioxin is computed based on the feed to Test 3 ( $4.25 \times 10^{-5}$  kg) as compared to that in the offgas ( $3.17 \times 10^{-9}$  kg).

Similar destruction efficiencies are observed for furans. The feed contains  $2.29 \times 10^{-5}$  kg of total furans, of which  $4.98 \times 10^{-9}$  kg are reported in the offgas (99.98% destruction).

### 7.3.8 Summary

In summary, overall material balance closure to within less than 3% was achieved. The major overall discrepancy was the reported offgas flowrate in the melter exhaust; when this was corrected to close the material balance on nitrogen, both carbon and oxygen were brought into very good closure. Solids, water, and carbon dioxide mass throughputs are also in very good agreement with predictions based on calcination chemistry. Most mineral oxide species show mass balance closure to within 10%, with only 1% of total  $MO_x$  species being entrained into the offgas. Aluminum, chromium, and phosphorus were all incorporated into the glass from dissolution of refractory. Most RCRA metals exhibit mass balance closure to within 5 to 30% overall, although closure around the plasma melter is much worse and does not permit accurate assessment of the fraction of each species retained in the glass product. Significant volatility loss of Cd, Hg, Pb, As, and Zn are expected, and supported by the data. Sulfur is also poorly characterized, but the low  $SO_2$  analysis coupled with theoretical calculations suggests that most sulfur is converted to sodium sulfate and reports to the glass melt. Overall organic destruction efficiency in the Phase II test is computed at 99.9999% - all SVOCs are destroyed, 99.99% of dioxins, and 99.98% of furans.

## 8. PHASE II PILOT DECONTAMINATION RESULTS

Plasma Vitrification destroys all organics because of the extremely high temperatures, above 2000°C, to which the molecules are exposed. Metals are incorporated into the glass product or they are volatilized into the gas stream. Metals in the gas stream are removed in a gas scrubber. The offgas temperature is reduced to condense and precipitate volatilized metals; most volatilized metals are captured in a particulate oxide form. The decontamination performance measured in the Phase II Pilot Test is summarized in this section. Specific pilot stream data are discussed in more detail in Section 11 where the environmental impact of all process output streams is discussed.

### 8.1 ORGANIC DESTRUCTION

Phase II Pilot Tests show essentially complete organic destruction, 99.9999% overall, as expected in the high temperature plasma system. The decontamination performance achieved in Phase II Pilot Tests is summarized in Table 8.1 by organic type. Both product glass analysis and melter offgas analysis are presented.

There are many ways to compute the decontamination performance of a processing system. The computed performance provided here has the following basis:

- Measured organic concentrations in the melter offgases, before any gas cleaning occurred, are used to compute destruction efficiency. This computation truly measures destruction, rather than removal, because it indicates that no organics are present in the melter's direct offgases. If dioxins were present in this gas, for example, they could be removed downstream in particulate collection equipment. The dioxins would be, in this case transferred into the particulate waste, but not destroyed as in the Plasma system. Furthermore, if the pilot gases were cleaned, the offgases would have lower organic concentrations; computed destruction efficiencies would be even greater.
- Organic destruction is computed using the values of trace hazardous organics only. Hazardous organics are present at much lower concentrations than other organics in the feed sediment, such as oils. If all organics were included in the destruction efficiency computation, the destruction efficiency computed would be orders of magnitude higher.

Table 8.1 Organic Destruction Was Essentially Complete

Chemical Analysis	Untreated Dry Sediment	Product Class	Melter Offgases Before Cleaning	Destruction Efficiency, %
PCBs(ug/kg or ppb)	7000	< Detection Limit	< Detection Limit	100
Semivolatiles (ug/kg or ppb)			All "hits" were flagged	100
di-n-butyl phthalate <sup>a</sup>	460	49 <sup>b,c</sup>	< Detection Limit	
bis-2-ethylhexylphthlate <sup>a</sup>	123,000	2584 <sup>b,c</sup>	< Detection Limit	
n-nitrosodiphenylamine	< Detection Limit	17 <sup>c</sup>	< Detection Limit	
All Others	111,700	< Detection Limit	< Detection Limit	100
Dioxins (ng/kg or ppt)	3860	< Detection Limit	0.07	99.99
2,3,7,8 TCDD (ng/kg or ppt)	19	< Detection Limit	< Detection Limit	100
Furans (ng/kg or ppt)	12,400	0.480 <sup>b</sup>	0.55	99.98
Total Organics, ppb	119,000	0.00048 <sup>b</sup>	0.88	99.9999

a) Common contaminant in analytical laboratory solvents

b) Blank sample was contaminated with this compound, indicating that the sample was probably contaminated

c) The value was estimated. The peak was observed below quantitation limits. This is another indication of questionable data.

- The computation sums organics detected in both the glass and the melter offgas to determine the quantity of residual organics, the total organics that are not destroyed.
- Analytical assays with data flags that indicate blank contamination, estimates were made below analytical quantitation limits, or estimates were below analytical detection limits were not included in the reported organic concentrations. Flagged data is discussed further in Section 11's evaluation of the environmental impact of the glass and offgas streams.
- Semivolatiles reported as flagged data in the output streams were eliminated from the feed organic calculation also, even when the feed analytical data was not flagged. The computed destruction efficiency was, therefore, based on a smaller organic input. This results in lower computed destruction efficiencies than those that would be reported if all organic input were included.
- The input hazardous organics used in the computations were the amounts measured in the plasma feed. This was actually a higher value, due to sampling errors, than that measured in the initial raw sediment. If initial sediment values are used in the calculations, the destruction efficiencies are higher.
- The calculations compute plasma destruction efficiency, not total sediment feed organic destruction. Obviously, we are not destroying organics in the oversized material fraction or the filtrate water. The filtrate water contained 0.27% of the feed sediment's semivolatiles, but essentially no dioxins or furans.

## 8.2 METALS PARTITIONING

Metals are not destroyed in the plasma process, but most metals are incorporated into the product glass, rendering them harmless. As discussed in the Material balances in Section 7, the Pilot Test results indicate that about 80% of the RCRA metals are retained in the product glass. The glass does not leach the metals as indicated by TCLP tests on the glass produced. Table 8.2 shows that the pilot glass passes all TCLP leach tests by factors of 100 to 1000.

Table 8.2 Pilot Glass Safely Incorporates RCRA Metals

<b>Contaminant Metals</b>	<b>Initial Dry Sediment Analysis, (mg/kg, ppm)</b>	<b>Pilot Glass Analysis (mg/kg, ppm)</b>	<b>Brookhaven TCLP Analysis (mg/L, ppm)</b>	<b>Regulatory TCLP Limit (mg/L, ppm)</b>
Ag, Silver	16	3	< Detection Limit	5.0
As, Arsenic	31	5	< Detection Limit	5.0
Cd, Cadmium	33	27	0.001	1.0
Cr, Chromium	342	988	0.060	5.0
Cu, Copper	1160	1061	0.134	1.4
Hg, Mercury	2	< Detection Limit	< Detection Limit	0.2
Ni, Nickel	252	256	0.030	
Pb, Lead	587	107	0.014	5.0
Se, Selenium	5	2	0.003	1.0
Zn, Zinc	1690	1233	0.166	

## 9. BENEFICIAL REUSE EVALUATION

Phase II Pilot Tests produced significant quantities of glass for testing potential beneficial reuse possibilities. The composition and properties of this glass are summarized in Table 9.1

**Table 9.1 Sediment Glass Composition Specification**

<b>Glass Properties:</b>		
Glass Fluxes Added	CaCO <sub>3</sub> and Na <sub>2</sub> CO <sub>3</sub>	
Ratio of CaO:Na <sub>2</sub> O in Flux	2.09	
Sediment Loading	83.2%	
Predicted T-200	1350°C	
<b>Glass Composition:</b>		
Component	Composition without Glass Fluxes (wt. %)	Composition with Glass Fluxes (wt. %)
SiO <sub>2</sub>	66.67	55.48
Al <sub>2</sub> O <sub>3</sub>	13.48	11.22
Fe <sub>2</sub> O <sub>3</sub>	8.14	6.77
MgO	2.62	2.18
K <sub>2</sub> O	2.52	2.10
CaO	2.40	13.90
NaCl	1.52	1.27
Na <sub>2</sub> O	1.34	5.99
TiO <sub>2</sub>	1.06	0.88
CuO/ZnO	0.25	0.21

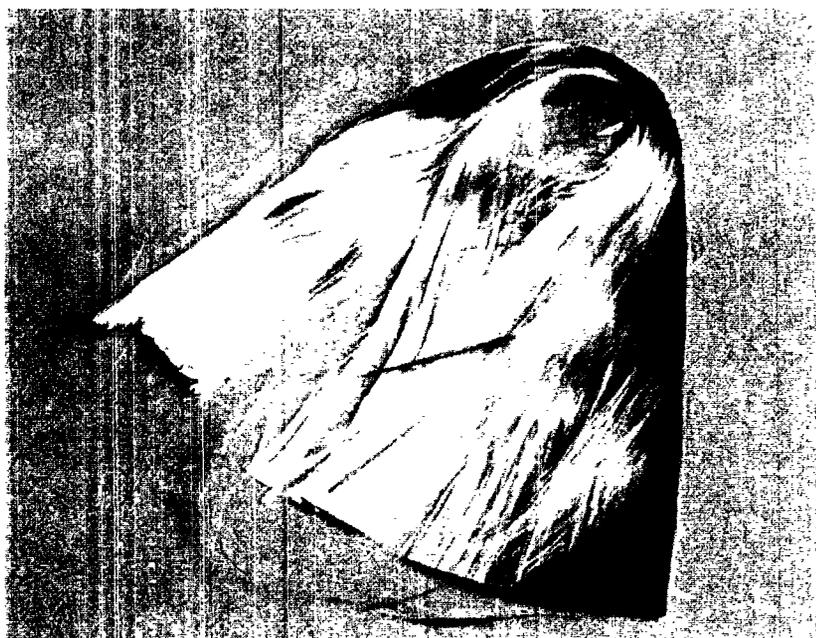
Westinghouse is proceeding to work with glass manufacturers to identify target options for producing high value glass products from the molten glass produced from New York/New Jersey Harbor sediment. Following a market survey that indicated many viable product options exist, Westinghouse entered discussions with several glass manufactures under confidentiality agreements.

There are many possibilities for the product glass use. Two product applications that are particularly promising are described below. Westinghouse is

seeking funding to demonstrate the manufacture of potential glass products from the sediment.

### **9.1.1 Glass Fiber Manufacturing**

Glass from the Westinghouse bench scale tests was tested by a glass fiber manufacturer and found to spin into a glass fibers with good physical properties. Figure 9.1 shows sample glass fibers spun from the bench scale glass. Similar fiber glass products have values of hundreds of dollars per ton. Prospective product and market options are being assessed by a manufacturer.



**Figure 9.1 High Strength Glass Fibers Made from Sediment Glass**

### **9.1.2 Glass Tile Production**

Laboratory testing by a glass tile manufacturer has also shown considerable promise. The photograph in Figure 9.2 shows a trial laboratory tile made using sediment glass made during the Phase II Pilot Test. Glass tile has wide distribution and a high market value, up to \$500/ton. Preliminary tests indicate that there is an excellent potential for manufacturing a high value glass tile for flooring or walls.



Figure 9.2 Laboratory Test Tile Indicates High Value Product Opportunity

### 9.1.3 Other Product Market Applications

Several other glass product options (i.e., aggregates, solar glass, rock wool, and roofing granules) are also possibilities.

Another attractive market would be production of rock wool, salable at roughly \$200/ton. This material is typically made at large volume (comparable to the 8,500 lb/hr anticipated for the 100,000 cy/yr treatment plant) by blowing fibers off of rotating wheels in large tanks of molten slag; the process is also very tolerant of nonvitreous inclusions. The raw material for rock wool production has traditionally been steel mill slag, which is remelted with coke. Recently, this market has suffered from environmental regulation due to the sulfur emissions inherent with both mill slag and coke. The glass product from Plasma Melting will be low in sulfur. The proximity of the large urban market in the New York/New Jersey area is another advantage; because of the low density of rock wool, transportation costs make it prohibitive to manufacture the material more than 100-200 miles from the final market.

Additional potential markets for sediment slag is the production of roofing granules, used as a barrier on asphalt roofs and shingles to protect the asphalt from ultraviolet degradation. These are again made of remelted minerals and command a significantly higher value than rock wool. The fabrication of these granules is somewhat more demanding than rock wool, since variations in the iron concentration and oxidation-reduction potential can significantly change the ultraviolet absorption properties of the granules. The  $Fe^{+3}/Fe^{+2}$  ratio in the sediment glass is very high, which would create conditions that would be highly absorbing for ultraviolet, making this material a good candidate for such granules. Further consideration of the physical and mechanical properties of the final glass particles and techniques for producing the desired particle size is required the market potential.

## 10. ENERGY REQUIREMENTS IN PILOT TESTS

One of the objectives of the pilot testing was to obtain data on the energy requirements for melting the sediment in the plasma reactor. Most of the pilot testing was performed at a constant energy input conditions to generate glass product. At the end of Test 3, however, we varied operating conditions to test the ability of the pilot torch configuration to respond to greater throughput with lower energy consumption.

Table 10.1 summarizes energy requirements obtained from the pilot tests. The average energy requirement (1.99 MWhr/ton of dredge feed) was slightly higher than our initial design base for a 500,000cy/year plant. The pilot unit was run,

Table 10.1 Energy Consumption in Phase II Pilot Tests

<b>PILOT DATA</b>	<b>Average Pilot Performance</b>	<b>Best Pilot Performance</b>
Plasma Feed, lb/min	20	25
% Solids in pilot plasma feed	51	56
lb dry sediment/ lb dry feed	0.79	0.8
lb dredge feed/hr	1612	2240
MWe	1.6	1.5
MWhr/ton dredged feed	1.99	1.34
<b>Scaleup Projection</b>		
MWe for 500,000 cy/yr plant	124	84

however, at conditions demonstrating much lower energy consumption, 1.34 MWhr/ton of dredge feed. Scaling this energy consumption a 500,000cy/yr plant will require 84Mwe. This test result is particularly encouraging since the pilot torch configuration is not optimal for heat transfer to the sediment or melting. A production-scale or full-scale facility, will, in all likelihood, have lower energy requirements than that demonstrated in the pilot unit. To be conservative, the updated design supplied in Section 12 will be based on the these pilot results.

## 11. ENVIRONMENTAL IMPACT OF PROCESS STREAMS

The major stream leaving the Westinghouse Plasma Vitrification Process is the product glass. The process achieves tremendous volume reduction; the glass produced has a total volume of less than one-sixth of the volume of the starting sediment. Since the potentially hazardous contaminated sediments are vitrified into a reusable product, the Westinghouse Plasma Vitrification Process alleviates the need for ocean dumping of any processed material, eliminating a major public relations concern and possible environmental hazard. In addition, it eliminates the need for disposal in offshore mud dumps. Conversion of contaminated sediments into a product avoids the environmental impact of opening further dumping grounds. Waste from processing the overall sediment stream will be reduced to about 3% of the original sediment feed weight. The process is environmentally sound, producing clean air and water discharges, non-contaminated calcium sulfate suitable for sanitary landfilling, and a small amount of stabilized metals.

A summary of all process streams leaving the integrated Plasma Vitrification System is given in 11.1. There are a total of seven streams exiting the Westinghouse sediment vitrification process. They are shown in Figure 11.1. Each of these streams is described in the following sections. The environmental impact of each stream is discussed in the following sections. When possible, Phase II pilot

Table 11.1 Summary of All Process Output Streams  
(Sediment Feed of 100,000 cy/year)

Output Streams	Amount	Deposition
Glass Product	37,000 tons/yr	Sell as commercial product.
<b>Solid Waste: Process Solid Waste Is Only 2.7% of Input Feed</b>		
Gypsum, Calcium Sulfate	2,200 tons/yr (2% of sediment feed)	Nonhazardous landfill or Beneficial Reuse
Oversized Material	400 tons/yr	Nonhazardous landfill or Plasma vitrify in batches producing a stable slag.
Precipitated Metals from Scrubber Water	90 ton/yr (0.09% of sediment feed)	Encapsulate and dispose of as a nonhazardous waste in landfill, or recover heavy metals
<b>Clean Water:</b>		
Filtrate & Rinse Water	52 Mgal/yr	Return clean water to sewage.
Scrubber Water Bleed	0.7 Mgal/yr	Treat for removal of heavy metals; Return clean water to sewage.
Clean Offgases	2.4×10 <sup>9</sup> std cu ft/yr	Discharge to stack.

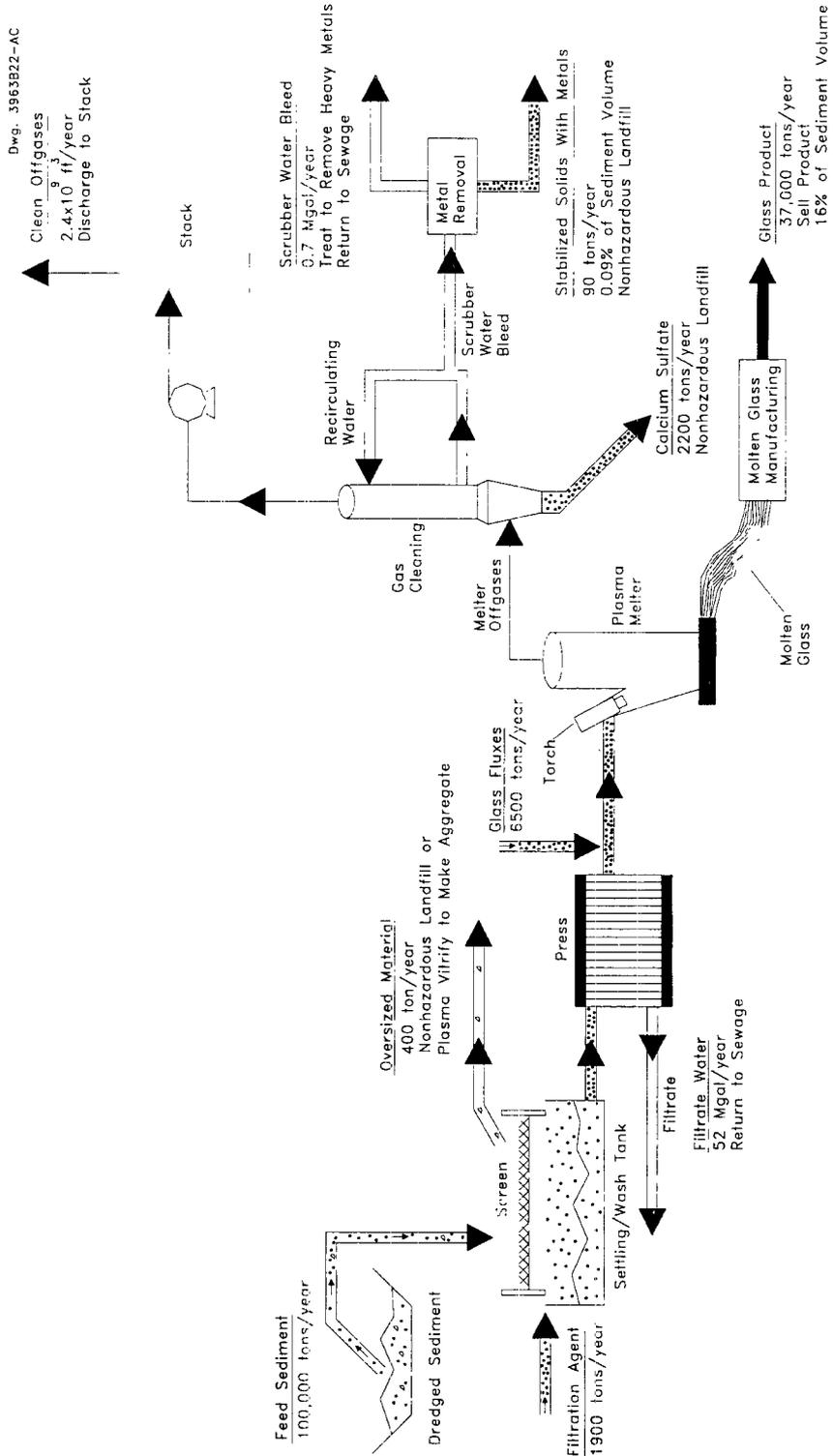


Figure 11.1 The Plasma Vitrification Process Minimizes Waste

data are used to assess the environmental impact of the output streams. The pilot data used in this evaluation are presented in Appendices A through G.

### 11.1 GLASS PRODUCT

Glass made from the decontaminated sediment will be formed into a useful product, potentially a product with a high market value. Glass is a stable compound; most of the sediment's hazardous metals will be incorporated into the glass where they will be nonleachable. Phase II test results on the product glass produced from Newtown Creek sediment show that it is essentially free of any organics, and that it contains metals that are not leachable to the environment.

*Five samples of the glass were thoroughly analyzed. The preponderance of evidence shows that the glass is organic free.*

Two types of organic analysis were performed on glass samples, chemical assays which are performed by extracting the glass with organic solvents and TCLP leaching tests which are performed by an acid extraction. Chemical assays were performed on two samples of pilot glass. TCLP leaching tests were performed on three samples of pilot glass. All analytically reportable "hits" for organics that were not disqualified because of blank contamination are summarized in Table 11.2 and discussed below.

Table 11.2 Organic Analytically Reportable Hits on Pilot Glass

Compound	Analysis	Flags	TCLP	Flags
Semivolatiles (64 assays)				
diethylphthalate	46 ppb	J, C, 1	Not Detected	
bis(2ethylhexyl)phthalate	Not Detected		0.73 ppb	J, C, 1
n-nitrosodiphenylamine	17 ppb	J, D, 1	Not Detected	
all others (64 assays)	Not Detected		Not Detected	
Dioxins	Not Detected		Not Detected	
Furans	Not Detected		7.7 ppq OCDF	1
PCBs	Not Detected		0.3 ppt	D, 2

J = below quantitation limits                      1 = found in only one of two or three samples  
D = below detection limits                            2 = found in two of three samples  
C = common analytical contaminant

- A total of three semivolatiles were reportable analytically.
  1. Diethylphthalate was reported in one the two chemical assays, but it was not detected in any of the three TCLP leachates. Diethylphthalate is a common contaminant found in analytical solvents. It tends to adhere to the containers and tubing used in analytical assay work. Furthermore, the reported value for this compound is below the analytical quantitation limits.

2. Bis(2-ethylhexyl)phthalate was reported in one the three TCLP leaching tests, but it was not detected in any of the two chemical assays. Bis(2-ethylhexyl)phthalate is another common contaminant found in analytical solvents because it tends to adhere to the containers and tubing used in analytical assay work. Furthermore, the reported value for this compound is below the analytical quantitation limits.
  3. N-nitrosodiphenylamine was reported in one the two chemical assays, but it was not detected in any of three TCLP leachates. The reported value of 17 ppb is below both the analytical quantitation limit and the analytical detection limit for this compound.
- No dioxins were detected in either glass or TCLP measurements.
  - Of the five glass assays performed, one TCLP assay had a reportable furan, 7.7 ppq OCDF ( $7.7 \times 10^{-15}$ ).
  - Of the five glass assays performed, two TCLP assays had reportable PCBs of 0.3 ppt ( $0.3 \times 10^{-12}$ ) in the leachate.

In summary, the few organics “hits” in the product glass that are analytically reportable are technically questionable because 1) they are all at the boundary of the analytical technique’s detection limits, 2) they have associated flags that indicate they are below quantitation limits of the instrument, and 3) they do not consistently appear in the five sample analyses performed.

***Metals detected in TCLP leaching tests were 100 to 1000 times below the concentrations set by any regulatory limits for hazardous indication.***

Table 11.3 summarizes the metal concentrations in the initial sediment and product glass, along with the TCLP results obtained on the glass. As discussed in Section 7’s review of the pilot test material balances, about 80% of the hazardous metals were retained in the glass. The glass remains nonhazardous. Leaching tests pass regulatory guidelines by several orders of magnitude.

Table 11.3 Metal TCLP Analysis of Pilot Glass

Contaminant Metals	Initial Dry Sediment Analysis, (mg/kg, ppm)	Pilot Glass Analysis (mg/kg, ppm)	Brookhaven TCLP Analysis (mg/L, ppm)	Regulatory TCLP Limit (mg/L, ppm)
Ag, Silver	16	3	< Detection Limit	5.0
As, Arsenic	31	5	< Detection Limit	5.0
Cd, Cadmium	33	27	0.001	1.0
Cr, Chromium	342	988	0.060	5.0
Cu, Copper	1160	1061	0.134	1.4
Hg, Mercury	2	< Detection Limit	< Detection Limit	0.2
Ni, Nickel	252	256	0.030	
Pb, Lead	587	107	0.014	5.0
Se, Selenium	5	2	0.003	1.0
Zn, Zinc	1690	1233	0.166	

## 11.2 CALCIUM SULFATE

Sulfur is present in the dredged sediment at a concentration of 2.7%; the sulfide concentration is 0.8% in the dredged sediment. Our current design of the integrated plasma vitrification system assumes that most of the sulfur will form SO<sub>x</sub> during the vitrification process. The sulfur oxides will then be cleaned from the offgas stream to produce a clean calcium sulfate waste stream. This waste will be generated in any thermal process. In other thermal processes, such as thermal desorption systems, sulfur can be condensed for later incineration. The incinerator will then produce the same calcium sulfate waste stream. Calcium sulfate can be disposed of in a nonhazardous landfill.

The size of the calcium sulfate stream is dependent on the amount of sulfur in the feed sediment. With Newton Creek sediment, the input sediment feed contains about 1% sulfur, 100,000 cy/year plant will generate 2200 tons/year of calcium sulfate for disposal. The Phase II Pilot test did not test the sulfur scrubbing system so no calcium sulfate product stream was produced from Phase II tests.

Phase II Tests results measured surprisingly low SO<sub>x</sub> levels in the melter gas. At high melter temperatures, sodium sulfate is the thermodynamically favored species so SO<sub>x</sub> levels in the melter offgas may indeed be small. Sodium sulfate is volatile, but it will be captured in the offgas scrubbing system for particulates. Offgas measurements and thermodynamic projections will be evaluated, along with air emission requirements in the Harbor to determine if any sulfur scrubbing is necessary. If sulfur scrubbing is not needed, the process flow diagram will be simplified, and there will be no calcium sulfate waste stream. The sulfur, in this case, will be stabilized with precipitated metals from the scrubber water.

### 11.3 OVERSIZED MATERIAL

Oversized material produced from the process will probably be directly landfilled. As an alternative, the material can be batch vitrified in a separate plasma operation to produce an inert slag or lower quality glass, reducing its volume and improving its stability.

Phase II testing produced 5.3% oversized material. We expect that dredged material will normally have a smaller percentage of oversized material because most of the oversized material resides in the top portion of the dredged sediment; Westinghouse's sediment batch was dredged from the top layer of sediment. An assumed percentage, 3% oversized material, is chosen for our design base.

The oversized material from the Westinghouse Phase II Pilot Test was not analyzed for contaminants. In fact, no oversized analysis was performed in the BNL testing of any process. We expect the material to be suitable to be directly landfilled.

### 11.4 FILTRATE WATER

The filtrate water from chloride removal and dewatering of the initial sediment is expected to meet discharge criteria for the New York/New Jersey area. A commercial plant will most likely obtain permit approvals to discharge this water directly to a sewage system.

Phase II testing produced 8651 gallons of filtrate water. This is a proportionately larger quantity than will be produced in actual operations. The amount of filtrate water was greater than required for a commercial operation because extra water was needed to pump the sediment from the rolloffs to the oversize cuttings screen. In practice, dredging operations will be coordinated with the screening and transport. Debris will be removed during dredging so pumping operations will be easier to carry out, less transport water will be needed. In addition, pump selection will be optimized for the commercial design.

Because calcium hydroxide was added to the sediment to facilitate dewatering in the press, filtrate water pH was high, 12.2. This will need to be reduced to below 10 for disposal. To eliminate this pH change, the commercial process will either use an alternative polymer filtering agent, avoiding the increased filtrate water's pH in commercial processing, or the water will be neutralized before discharge. We expect to neutralize the filtrate water during operations. Other general properties of the filtrate water from the pilot test were nondetect total sulfides and a total organic carbon content of 51 mg/L.

Table 11.4 summarizes filtrate water characteristics. Contaminants identified at detectable levels in the filtrate water were:

- SVOCs: 85 ppb of benzoic acid was the only semivolatile present above quantitation limits that was not also present in the blank sample.

- PCBs: 0.15 ppt of congener 15 was detected. All other PCBs detected were also present in the analytical blank, indicating a contamination problem.
- Dioxins: 7.9 ppq ( $7.9 \times 10^{-15}$ ) heptachlorinated dioxin, HpCDD, was the only dioxin detected.
- Metals detected in the filtrate water are summarized in Table 11.4 along with a comparison of how the filtrate water's contaminant concentrations compare with typical water discharge requirements and hazardous waste criteria.

The filtrate water analysis shows that the water meets discharge criteria except for its high pH. The high pH may have, in fact, adversely affected the water's contaminant content, allowing solubilization of some compounds that would remain in the solids phase at a normal pH. Demonstration testing will need to verify this assumption.

Table 11.4 Filtrate Water Will Meet Discharge Criteria

Compound	Amount Detected, ppm (BNL Analysis)	Amount Detected, ppm (MAX Environmental Analysis)	Typical Discharge Limits <sup>a</sup> , ppm	Toxic Criteria, ppm
TPH	1.8	NA <sup>b</sup>		
organic carbon	51	54		
reactive sulfide	NA <sup>b</sup>	70	500	
reactive cyanide	NA <sup>b</sup>	ND <sup>c</sup>	250	
Oil & Grease	NA <sup>b</sup>	44		
Total Solids	NA <sup>b</sup>	7640		
As	0.013	ND		5
Cd	ND <sup>c</sup>	ND	0.4	1
Cu	0.195	0.26	10.4	
Cr	ND <sup>c</sup>	0.03	13.6	5
Ni	0.130	0.22	8.0	
Pb	0.015	ND <sup>c</sup>	13.2	5
Se	0.079	ND <sup>c</sup>		1
Tl	0.006	NA <sup>b</sup>		
Zn	0.174	0.23	12.5	
Hg	0.005	0.002		0.2

- a) Discharge limits for POTW in Pittsburgh      c) ND = nondetect  
 b) NA = analysis not available

### 11.5 SCRUBBER WATER BLEED

The Phase II testing produced 3700 L of scrubber water with a pH of 8.3. The scrubber water pH will be regulated by on-line control in the commercial system. The scrubber water's total sulfide level and organic carbon content were both below the detection limit.

The pilot test's scrubber water contained the following concentrations of contaminants:

- SVOCs: none detectable other than bis-2-ethylhexylphthalate, a common analytical contaminant
- PCBs: 35 ppt of PCBs.
- Dioxins: 1.5 ppt total dioxins and 10.8 ppt total furans.
- Metals found in the scrubber water are summarized in Table 11.5.

Several metals (i.e., cadmium, chromium, and lead) are present in concentrations that cause the scrubber water to be classified as hazardous.

The pilot test scrubber water was treated by Envirite of Ohio. Envirite precipitated the metals to create insoluble metal compounds. Along with the proprietary precipitation process, the solids were stabilized in a calcium/magnesium matrix. The solid precipitate was disposed of as a nonhazardous waste in a Subtitle B landfill. The cost of scrubber water processing for the small quantity from the pilot test was \$0.40/gal. A cost quote for the large water volume generated from a production unit could be reduced to as low as \$0.03/gal. This water treatment

Table 11.5 Scrubber Water e Treated to Remove Hazardous Metals

Metal	Concentration, BNL Assay, ppm	Concentration, K Chem Scrubber Tank Assay, ppm	Regulatory Limit, ppm, mg/L <sup>a</sup>
Ag	0.38	0.51	5
As	0.79	0.34	5
Ba	NA	1.0	100
Cd	1.8	2.1	1
Cr	22.1	66.7	5
Cu	3.1		
Ni	0.28		
Pb	12	88.5	5
Sb	0.17		
Se	0.095	0.051	1
Tl	0.067		
Zn	51		
Hg	0.0011	<0.0005	0.2

a) CFR 261.24

b) NA = analysis not available

process generates about 0.25 lb of solid nonhazardous waste for disposal per gallon of water treated. Clean, treated water is discharged.

Thermodynamic projections indicate that the metals present in the gas stream will be in a particulate oxide form. Westinghouse's assessment from this data is that the metals carried into the gas stream will be in a particulate form that will be filterable from the scrubber water. The filtration may be another effective metal removal process for the scrubber water. A cost effective, environmental solution to scrubber water treatment will be defined in the preliminary design phase.

### **11.6 PRECIPITATED METALS FROM SCRUBBER WATER**

The scrubber bleed system from the plasma vitrification process will contain a small amount of volatile metals (e.g., cadmium, chromium, lead, and mercury) that are not encapsulated in the glass. The water will be treated to remove these trace metals, producing a small stabilized metal stream. Here again, any thermal process will result in this volatile metal carryover into the gas phase. Gas cleaning will result in a small metal stream for disposal.

The small quantity of volatile heavy metals which cannot be retained in a glass matrix (i.e., Cd, Pb, and Cr) will be removed in the scrubber bleed stream. This small, but contaminated liquid stream will be treated, possibly by precipitation and stabilization to remove the metals from the waste stream. The heavy metal precipitates will then be disposed of in a nonhazardous waste landfill. The clean water stream will be discharged.

The contaminated metals removed from the scrubber water could either be (1) stabilized and disposed of as nonhazardous waste, or (2) a process could be developed for recovery and separation of the various heavy metals precipitated.

The exact amount of this metal stream generated will depend on the water treatment process selected. Phase II pilot scrubber water was treated by Envirite of Ohio. We estimate, based on the pilot water treatment that a stabilized, nonhazardous metal stream equivalent to 0.09% of sediment feed (90 ton/year from a 100,000 cy/year plant) will result.

### **11.7 CLEAN OFFGASES**

The offgases leaving the plant will consist primarily of steam, air, and carbon dioxide. The scrubber system will have removed sulfur and nitrogen oxides, heavy metal vapors and salts, and entrained particulates that exit the plasma melter. Pilot test data verify that the offgases will contain no organics. Metals found in the pilot melter offgases will be effectively removed using a gas scrubber system.

### 11.7.1 Westinghouse Pilot Program Gas Analysis Measurements

During Test 3 of the plasma vitrification process, gases exiting the melter were directly sampled, before any gas cleaning or particulate removal was performed. The gases were samples by Affiliated Environmental using a one point traverse. One hour runs were performed to determine gas flow and composition by the following EPA techniques. Table 11.6 summarizes the measurement techniques used to determine the various components in the gas stream, along with the analytical testing laboratory used for each measurement. Appendix G contains sections of Affiliated Environmental's report that provides more detail on the sampling techniques, along with the summary data sheets used for the evaluation.

Table 11.6 Analytical Methods and Laboratories for Offgas Analysis

Assay	EPA Method	Analysis Laboratory
Gas Velocity, volumetric flow rate	Methods 1 and 2	Affiliated Environmental
Particulate content	Methods 1 to 5, 29	Affiliated Environmental
Particle size distribution	Model 226 Source Cascader	Affiliated Environmental
O <sub>2</sub> , N <sub>2</sub> , CO <sub>2</sub> , SO <sub>2</sub> , NO <sub>x</sub>	Methods 3, 3A, 4, and 6C, 7E	Affiliated Environmental
Argon	Methods 3, 3A, 4, and 6C, 7E	DATA Analysis Technology
Ag, As, Cd, Cu, Ni, Pb, Sb, Se, Ti, Zn, Hg	Method 29	Affiliated Environmental
Cl	Method 26A	Affiliated Environmental
PCBs, dioxins, furans, other organics	Collection Method 23	Triangle Laboratories

Affiliated Environmental measured the gas flow from the pilot unit during each gas sampling test. The Affiliated Environmental gas flow measurements are, however, in error because the measurement method is dependent on an assumption of isokinetic sampling in a nondisturbed flow regime. The pilot configuration has no sampling ports located in a position with an adequate straight run of ducting to allow accurate velocity measurement. The measured gas flows, therefore, cannot be used as the basis for computing gas concentrations. A computed gas flow from the mass balance provides a more accurate volumetric flow. Mass balance calculations indicate that gas flow measurement by Affiliated Environmental were high by a factor of about six. Table 11.7 displays the reported measurements, and measurements corrected by a nitrogen balance over the plasma reactor.

The general composition of the melter gases was 55.3% N<sub>2</sub>, 30.0% H<sub>2</sub>O, 12.0% O<sub>2</sub>, 1.6 % Ar, and 1.1 % CO<sub>2</sub>. The particulate loading in the melter offgases was 0.19 grains/dsft<sup>3</sup>, 5.07 lb/hr of operation, before any gas cleaning for particulate removal.

Table 11.7 Offgas Velocity Measurements from Pilot Tests

Test Method	Units	23	26	1-5, 29	3A, 6C, 7E	Average for All Tests
Velocity	ft/s	84.7	94.4	90.2	95.2	91.1
Velocity, Corrected	ft/s	14.0	15.5	14.9	15.7	15.0
Gas Flow	acfm	3994	4429	4249	4482	4289
Gas Flow, Corrected	acfm	658	729	729	738	706
Gas Flow	dcfm	2444	2522	3082	2493	2635
Gas Flow, Corrected	dcfm	403	415	508	411	434

All offgas analysis performed in the Phase II Pilot Tests were performed on the offgases collected from the duct directly exiting the plasma melter. **No gas cleaning was performed before sampling.** No particulate capture or removal occurred before the gas sampling. In this way, the assays can be used to help project metals partitioning in the plasma melter. The offgases do not, however, reflect the material to be emitted to the atmosphere. In any commercial unit, the gases will be cleaned in scrubbers and particulate filters before being emitted to the stack.

The Phase II Pilot Test data indicate that the gases will be very clean. Organic destruction was essentially complete; metals volatilized from the system are expected to be present in a solid oxide form that can be removed from the offgas stream. Specific pilot data are summarized below.

### 11.7.2 Concentrations of Organics in the Untreated Offgas Stream

*Organic assays of the melter offgases show essentially complete organic destruction.*

- No detectable semivolatiles are present, except in measurements that are flagged as estimated below quantitation limits or flagged as compounds that were present in the blank indicating a contamination problem. The compounds estimated below the quantitation limit are methylnaphthalene at 3.4 ppb, diethylphthalate at 9.5 ppb, and phenanthrene at 2.6 ppb.
- No 2,3,7,8-TCDD dioxin was detected in the melter offgases.
- No PCBs were detected in the melter offgases
- Dioxin and furan concentrations in the melter offgases are several orders of magnitude below any proposed or in place offgas emission standards. Keep in mind these are concentrations present in the melter offgas before any gas cleaning occurs.
- The computed toxic equivalencies of the melter offgas samples is only two times the value obtained from using the same toxicity calculation on the

analytical laboratory blank (i.e., clean sample) data. Given the extremely low levels of dioxins and furans that are attempted to be quantified, this assessment of the data is possibly the most revealing. It shows that the melter offgas samples are nearly equivalent in toxicity to a pure air sample.

It is important to remember several key points in interpreting the dioxin measurements

- The measurements were taken on gases samples before a cleaning occurred. Gas cleaning can be designed to remove 90% plus of the particulates and, therefore, significantly reduce dioxin levels emitted from the process.
- The pilot testing was performed with an existing pilot unit, fixed in its configuration. Three confirmation tests were performed without an attempt to optimize performance. During the pilot tests, fine particles of sediment were visually observed to bypass the torch's plume and impinge on the reactor wall, melting in a lower temperature area of the reactor. The residence time of sediment in the hottest zones of the plasma reactor will be increased in the commercial unit design, assuring destruction of organics.

The results of the dioxin/furan assays on gases exiting the melter are summarized in Table 11.8. Assays were performed on the front end of the filter train, collecting particles of greater than 5  $\mu\text{m}$  in diameter, and the back end of the filter train, collecting particles of less than 5  $\mu\text{m}$ .

The most toxic dioxin compound, 2,3,7,8-TCDD, was not detected. EPA has developed a method to define the toxicity of the many dioxin congeners in terms of this most toxic dioxin. Each furan and dioxin measured is multiplied by a factor according to its toxic equivalence to 2,3,7,8-TCDD. In order to assess the toxicity of the compounds detected or estimated from the analytical testing, we used EPA's method to determine the total toxicity of the sample. The calculation performed on the samples is provided in Tables 11.9 and 11.10.

Table 11.8 Dioxin and Furan Measurements

Analytes	> 5 um particles		<5 um particles	
	Amt. (ng)	Flags	Amt. (ng)	Flags
2,3,7,8-TCDD	ND <sup>a</sup>		0.002 <sup>b</sup>	
1,2,3,7,8-PeCDD	ND		ND	
1,2,3,4,7,8-HxCDD	ND		0.004 <sup>b</sup>	
1,2,3,6,7,8-HxCDD	ND		0.004 <sup>b</sup>	
1,2,3,7,8,9-HxCDD	ND		0.008	PR <sup>c</sup>
1,2,3,4,6,7,8-HpCDD	0.02 <sup>b</sup>		0.02	
1,2,3,4,6,7,8,9-OCDD	0.11		0.09	B <sup>d</sup>
2,3,7,8-TCDF	0.03 <sup>b</sup>		0.02	
1,2,3,7,8-PeCDF	ND		0.03	
2,3,4,7,8-PeCDF	ND		0.04	
1,2,3,4,7,8-HxCDF	ND		0.08	PR <sup>c</sup>
1,2,3,6,7,8-HxCDF	ND		0.04	
2,3,4,6,7,8-HxCDF	0.02 <sup>b</sup>		0.04	B <sup>d</sup> , PR <sup>c</sup>
1,2,3,7,8,9-HxCDF	ND		0.007	
1,2,3,4,6,7,8-HpCDF	ND		0.08 <sup>b</sup>	
1,2,3,4,7,8,9-HpCDF	ND		0.02 <sup>b</sup>	
1,2,3,4,6,7,8,9-OCDF	0.05 <sup>b</sup>		0.05	B <sup>d</sup>
<b>Totals</b>	<b>Amt. (ng)</b>	<b>Flags</b>	<b>Amt. (ng)</b>	<b>Flags</b>
Total TCDD	ND		0.03	
Total PeCDD	0.01 <sup>b</sup>		0.03 <sup>b</sup>	
Total HxCDD	0.02		0.03	
Total HpCDD	0.04 <sup>b</sup>		0.05	
Total TCDF	0.02		0.96	
Total PeCDF	0.02 <sup>b</sup>		0.57	
Total HxCDF	0.03 <sup>b</sup>		0.49	
Total HpCDF	ND		0.03	E <sup>e</sup>

a) ND = nondetect

b) estimated maximum possible concentration

c) PR = poorly resolved GC peak

d) B = compound present in analytical blank and field sample

e) E = PCDF peak eluted at same time as diphenyl ether

Table 11.9 Toxicity Equivalents for Gas Analysis, First Run

Analytes	< 5 um Particles				Field Blank		Lab Blank		
	Amt. (ng)	TEF		Equiv- alent	Amt. (ng)	Equiv- alent	Amt. (ng)	Equiv- alent	
2,3,7,8-TCDD	0.002	X	1	=	0.002	0.004	0.004	0.006	0.006
1,2,3,7,8-PeCDD	0.004	X	0.5	=	0.002	0.007	0.0035	0.01	0.005
1,2,3,4,7,8-HxCDD	0.004	X	0.1	=	0.0004	0.01	0.001	0.01	0.001
1,2,3,6,7,8-HxCDD	0.004	X	0.1	=	0.0004	0.008	0.0008	0.01	0.001
1,2,3,7,8,9-HxCDD	0.008	X	0.1	=	0.0008	0.008	0.0008	0.01	0.001
1,2,3,4,6,7,8-HpCDD	0.02	X	0.01	=	0.0002	0.01	0.0001	0.009	0.00009
1,2,3,4,6,7,8,9-OCDD	0.09	X	0.001	=	0.00009	0.02	0.00002	0.03	0.00003
<b>TOTAL PCDD</b>					<b>0.00589</b>		<b>0.0102</b>		<b>0.0141</b>
2,3,7,8-TCDF	0.02	X	0.1	=	0.002	0.004	0.0004	0.004	0.0004
1,2,3,7,8-PeCDF	0.03	X	0.05	=	0.0015	0.005	0.00025	0.007	0.00035
2,3,4,7,8-PeCDF	0.04	X	0.5	=	0.02	0.004	0.002	0.006	0.003
1,2,3,4,7,8-HxCDF	0.08	X	0.1	=	0.008	0.006	0.0006	0.006	0.0006
1,2,3,6,7,8-HxCDF	0.04	X	0.1	=	0.004	0.005	0.0005	0.005	0.0005
2,3,4,6,7,8-HxCDF	0.04	X	0.1	=	0.004	0.006	0.0006	0.008	0.0008
1,2,3,7,8,9-HxCDF	0.007	X	0.1	=	0.0007	0.007	0.0007	0.007	0.0007
1,2,3,4,6,7,8-HpCDF	0.08	X	0.01	=	0.0008	0.006	0.00006	0.005	0.00005
1,2,3,4,7,8,9-HpCDF	0.02	X	0.01	=	0.0002	0.009	0.00009	0.007	0.00007
1,2,3,4,6,7,8,9-OCDF	0.05	X	0.001	=	0.00005	0.01	0.00001	0.01	0.00001
<b>TOTAL PCDF</b>					<b>0.0413</b>		<b>0.00521</b>		<b>0.00648</b>
<b>Total EPA TEFs, 1989a</b>					<b>0.0471</b>		<b>0.0154</b>		<b>0.0206</b>

Table 11.10 Toxicity Equivalents for Gas Analysis, Rerun

Analytes	Amt. (ng)	< 5 um Particles			Lab Blank	
		TEF	Equivalent	Amt. (ng)	Equivalent	
2,3,7,8-TCDD	0.02	X	1 = 0.02	0.03	0.03	
1,2,3,7,8-PeCDD	0.05	X	0.5 = 0.025	0.03	0.015	
1,2,3,4,7,8-HxCDD	0.08	X	0.1 = 0.008	0.03	0.003	
1,2,3,6,7,8-HxCDD	0.07	X	0.1 = 0.007	0.02	0.002	
1,2,3,7,8,9-HxCDD	0.07	X	0.1 = 0.007	0.02	0.002	
1,2,3,4,6,7,8-HpCDD	0.11	X	0.01 = 0.0011	0.03	0.0003	
1,2,3,4,6,7,8,9-OCDD	0.20	X	0.001 = 0.0002	0.07	0.00007	
<b>TOTAL PCDD</b>				<b>0.0683</b>	<b>0.0524</b>	
2,3,7,8-TCDF	0.03	X	0.1 = 0.003	0.03	0.003	
1,2,3,7,8-PeCDF	0.03	X	0.05 = 0.0015	0.02	0.001	
2,3,4,7,8-PeCDF	0.03	X	0.5 = 0.015	0.02	0.01	
1,2,3,4,7,8-HxCDF	0.09	X	0.1 = 0.009	0.02	0.002	
1,2,3,6,7,8-HxCDF	0.04	X	0.1 = 0.004	0.02	0.002	
2,3,4,6,7,8-HxCDF	0.05	X	0.1 = 0.005	0.02	0.002	
1,2,3,7,8,9-HxCDF	0.06	X	0.1 = 0.006	0.02	0.002	
1,2,3,4,6,7,8-HpCDF	0.07	X	0.01 = 0.0007	0.02	0.0002	
1,2,3,4,7,8,9-HpCDF	0.07	X	0.01 = 0.0007	0.03	0.0003	
1,2,3,4,6,7,8,9-OCDF	0.17	X	0.001 = 0.00017	0.06	0.00006	
<b>TOTAL PCDF</b>				<b>0.0451</b>	<b>0.0226</b>	
<b>Total EPA TEFs, 1989a</b>				<b>0.113</b>	<b>0.0749</b>	

Using this ranking, it is interesting to note that the total toxicity of the fine particle sample collected, the most toxic of the samples, is only about twice the toxicity of the analytical blank sample. Because of the very low levels of compounds being detected, we requested that a duplicate run be made on dioxin and furan assays. In the duplicate run, all dioxin concentrations increased, in both blanks and in the test sample. The duplicate run analytical blank, a clean sample with no contamination run alongside the plasma offgas sample, had a dioxin toxic equivalency value equal to two-thirds of the value obtained for the melter offgases before any gas cleaning was performed.

The measurements reported in Table 11.8 were converted to a melter gas concentration by dividing the weight detected by the volume of gas that was sampled in order to collect the filter material. The dioxin and furan measurements are summarized in Table 11.11. Here the concentration of dioxins and furans is computed using three different bases - 1) using verified data that are not estimates of maximum possible concentrations, 2) using a toxic equivalence calculation on this verified data, and 3) using total specifically analyzed concentrations that include data with cross contamination, poorly resolved peaks, and estimates of maximum concentrations.

Table 11.11 Melter Offgas Dioxin Measurements, No Gas Cleaning

Compound	Amount on Filter, ng	Dry Gas Concentration, pg/dscm	Proposed Standard, pg/dscm	Gas Concentration (BNL), ppt	Gas Concentration (Westinghouse) <sup>a</sup> , ppt
<b>Using Verified Data</b>					
Dioxins	0.028	19.9	200	0.0116	0.0705
Furans	0.217	153		0.09	0.5463
<b>Computing Toxic Equivalency Using Verified Data</b>					
TEQ Dioxins	0.0058	4.1	200	0.0024	0.0146
TEQ Furans	0.0372	26.4		0.0154	0.0936
<b>Using Total Dioxin Data, Including Data with Cross Contamination</b>					
All Dioxins	0.132	93.6	13,000	0.0547	0.3323
All Furans	0.407	288.6		0.1687	1.0246

a) Westinghouse computed a higher concentration to correct for offgas flow measurement errors.

Whatever method is used to represent the concentrations, the melter offgases meet all current and proposed offgas emission standards by orders of magnitude before any gas cleaning occurs.

### 11.7.3 Concentrations of Metals in the Untreated Offgas Stream

Offgas metals analysis were performed by Affiliated Environmental. Table 11.12 summarizes the metals concentrations measured in the direct melter offgas using the measured flowrate, along with the corrected concentration using

material balance calculations on the gas stream to correct the gas flowrate. Again, note that these concentrations are present before any gas cleaning is performed.

Thermodynamic projections indicate that all hazardous metals will be present in particulate forms, primarily particulate oxides, in the scrubber. There will be, therefore, no problem in capturing these metals from the melter in a gas scrubbing system. Using commercial scrubber systems, the plant offgases will be cleaned to meet all environmental standards.

Table 11.12 Metals Analysis in Gas Stream

Compound	Concentration, mg/dscm	Corrected Concentration, mg/dscm
Sb	0	0
As	0.005294	0.03214
Ba	0.013507	0.0820
Be	ND	ND
Cd	3.057	18.56
Cr	5.684	34.51
Cu	0.6515	3.956
Pb	0.6684	4.058
Hg	0.002149	0.01305
Ni	2.0512	12.454
Se	0.00013	0.000789
Ag	0.2327	1.412
Na	6.088	36.96
Ti	0.05869	0.3563
Zn	19.608	119.05
S	61.96	376.20

## 12. PRODUCTION- AND FULL-SCALE OPERATIONS

A summary of the design of production-scale and full-scale operations of Westinghouse's integrated plasma vitrification process for decontaminating New York/New Jersey sediments is described in this section. The information provided is based on our current design basis, including information available from the Phase II Pilot Testing.

Westinghouse's approach to solving the sediment decontamination problem is to provide an integrated plasma vitrification process, a complete treatment train to (1) decontaminate the sediment, (2) produce a useful commercial glass product, and (3) minimize waste from contaminated sediment processing. Westinghouse assessed system design options for sediment decontamination. The major factors that have lead us to select the integrated plasma vitrification process as our base technology are:

- a drive to minimize hazardous waste and maximize resource recovery;
- process simplicity with flexibility to accept variable sediment feeds;
- the need for low processing cost (less than \$100/ton); and
- the need for production of a high value product that can partially or completely subsidize plant operations.

There are many process design tradeoffs that need to be evaluated in order to optimize the plasma vitrification process. Some of these design options include:

- feed options to the plasma melter (e.g., pretreatment versus direct feed systems are possible);
- oversized material processing options;
- pretreatment options (e.g., desalination, sizing, dewatering);
- plasma melter design options (e.g., feed system options, reactor design specifics, glass removal methods);
- offgas treatment options; and
- scrubber water treatment options.

Our current assessment of these options results in the following design of an integrated Plasma Vitrification Treatment Train.

Section 12.1 presents a description of the integrated Plasma Vitrification Treatment Train's treatment units and the process material balance. Section 12.2 provides the system's energy balance. A description of the envisioned plant configuration is given in Section 12.3. Production requirements are summarized in Section 12.4. Using this current design base, the capital and operating costs for a 500,000 cy/year sediment decontamination plant are estimated in Section 12.5.

## **12.1 PROCESS DESCRIPTION AND MATERIAL BALANCES**

Figure 12.1 presents an overall flowsheet for the integrated Plasma Vitrification process. Streams numbers refer to material balance calculations in Table 12.1 and Table 12.2. Material balances are computed for the production-scale operation of 100,000 cy/yr. Material balances are based on actual sediment compositions and processing parameters determined in the Phase I and Phase II test programs. The overall process is segmented into two major operations in this material balance, namely sediment pretreatment (designed to size classify and dewater the sediment) and vitrification. The six major elements of the integrated plasma vitrification treatment train are described in the following sections. In addition, the optimum water content for dredged materials and the intellectual property status of the Plasma Vitrification Process are discussed.

### **12.1.1 Sediment Size Segregation**

Although the plasma melter can be designed to process the as-received sediment, the most economical system will probably incorporate the removal of large particles and debris. Incoming sediment (Stream 1) is first screened to remove particles larger than 1000  $\mu\text{m}$ . Removal of larger particles ensures that the rapid heat transfer experienced later in the plasma melter will fully melt the sediment particles, forming a homogeneous glass product. Removal of extraneous large particles also controls the input feed composition for product glass production. Screening and particle size analysis indicate that roughly 1 to 3% of the total as-dredged sediment mass will be classified as oversized by the process (Stream 3). Typically, contamination levels for large particles is much lower than that for finer material, so landfilling of this material may be the best option. If landfilling or other disposal options are not possible, the oversize material can also be vitrified. A separate vitrification melter could be used for this purpose, with a feeding system specifically designed for large material.

The rinse water removed from the oversized fraction is mixed with the undersize screen fraction to be dewatered in a filter press.

### **12.1.2 Sediment Rinsing and Dewatering**

The next step in pretreatment of the sediment is removal of the bulk of the salt water from the sediment. Removal of salt is desirable to avoid operating and

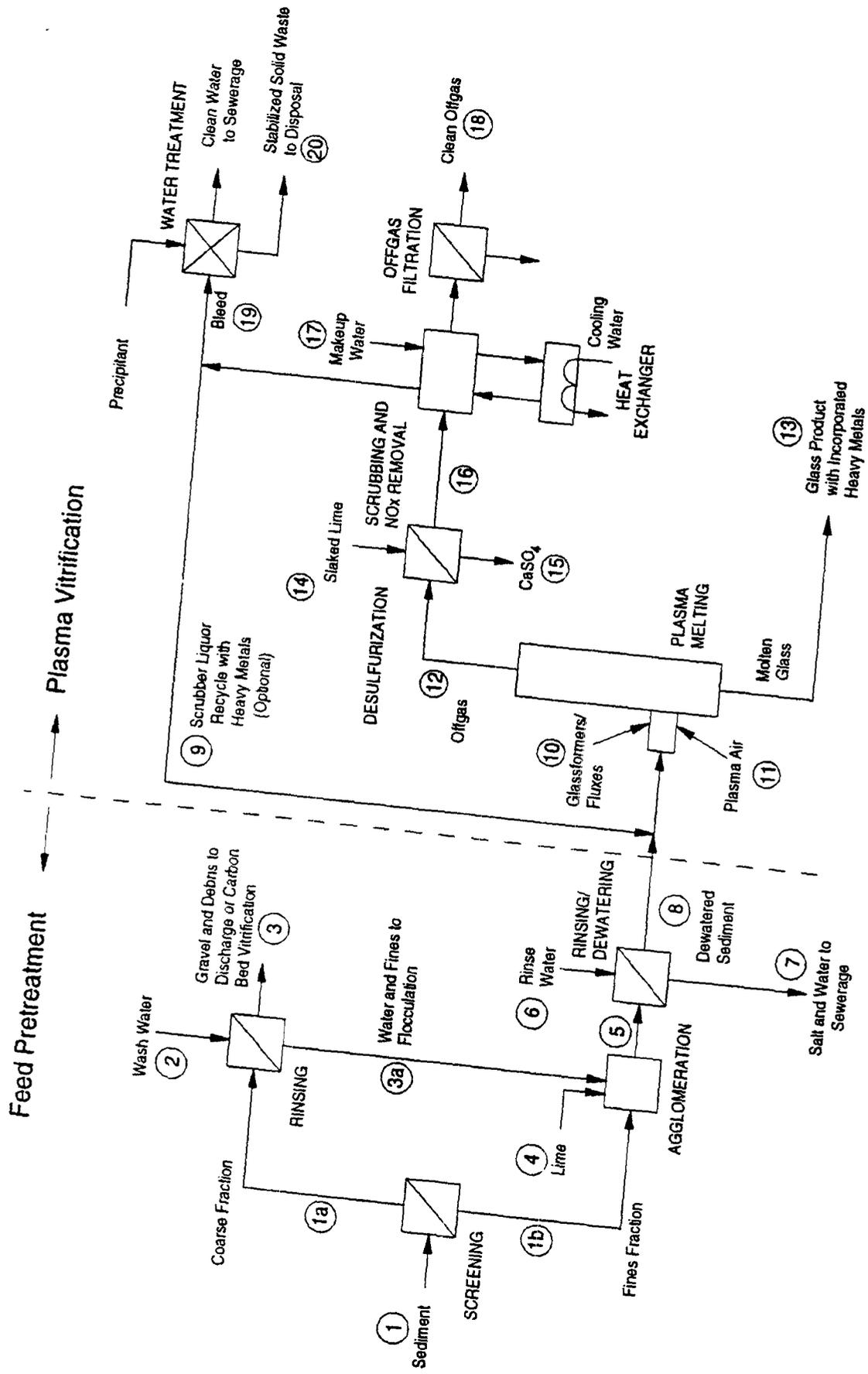


Figure 12.1 Integrated Plasma Vitrification Process Flow Diagram

Table 12.1 Material Balance for the Sediment Pretreatment Plant

Stream tons/yr	1 Sediment	1a Oversize	1b Fines	2 Wash Water	3 Sand and Gravel	3a Oversize Rinse	4 Lime Filter Aid	5 Filter Feed	6 Rinse Water	7 Discharge Water	8 Dewatered Sediment
Solids											
Al <sub>2</sub> O <sub>3</sub>	3,127.8	34.4	3,093.4		34.4	0.0		3,093.4			3,093.4
SiO <sub>2</sub>	25,151.4	276.8	24,874.6		276.8	0.0		24,874.6			24,874.6
K <sub>2</sub> O	523.5	5.8	517.8		5.8	0.0		517.8			517.8
MgO	448.0	4.9	443.1		4.9	0.0		443.1			443.1
Fe <sub>2</sub> O <sub>3</sub>	630.6	6.9	623.7		6.9	0.0		623.7			623.7
FeO	567.4	6.2	561.2		6.2	0.0		561.2			561.2
CaO							3,018.8	3,018.8			3,018.8
Ca(OH) <sub>2</sub>											
CaSO <sub>4</sub>											
Na <sub>2</sub> O											
Na <sub>2</sub> CO <sub>3</sub>											
NaCl	264.6	2.9	261.7		2.9	0.0		261.7		156.9	104.8
S	2,866.4	31.5	2,834.9		31.5	0.0		2,834.9			2,834.9
C <sub>10</sub> H <sub>20</sub> -1	346.3	3.8	342.5		3.8	0.0		342.5			342.5
Water of Hydration	145.4	1.6	143.8		1.6	0.0		143.8			143.8
Heavy Metals	34,071.5	375.0	33,696.5	0.0	375.0	0.0	3,018.8	36,715.4	0.0	156.9	36,558.5
Total											
Liquids											
H <sub>2</sub> O	69,787.4	768.0	69,019.3	2,496.2	1,493.3	1,772.8		70,792.1	168,404.2	215,597.3	23,598.9
NaOH											
NaCl	2,119.2	23.3	2,095.9		10.7	12.7		2,108.5		1,897.7	211.9
NaNO <sub>3</sub>											
Total	71,906.6	791.4	71,115.2	2,496.2	1,504.0	1,785.5	0.0	72,900.7	168,404.2	217,495.0	23,810.9
Gases											
H <sub>2</sub> O											
N <sub>2</sub>											
O <sub>2</sub>											
Ar											
CO <sub>2</sub>											
SO <sub>2</sub>											
NO <sub>x</sub>											
NaCl											
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	105,978.1	1,166.3	104,811.7	2,496.2	1,879.0	1,785.5	3,018.8	109,616.0	168,404.2	217,651.9	60,369.3

Table 12.2 Material Balance for the Sediment Vitrification Plant

Stream	9	10	11	12	13	14	14	14	16	17	18
tons/yr	Scrubber Recycle	Fluxes	Plasma Air	Plasma Offgas	Glass Product	Desulfurizer Lime	Calcium Sulfate	Desulfurizer Offgas	Scrubber Makeup	Clean Offgas	
<b>Solids</b>											
Al <sub>2</sub> O <sub>3</sub>				92.8	3,000.6		92.8				
SiO <sub>2</sub>				746.2	24,128.3		746.2				
K <sub>2</sub> O				15.5	502.2		15.5				
MgO				13.3	429.8		13.3				
Fe <sub>2</sub> O <sub>3</sub>				37.4	1,209.9		37.4				
FeO											
CaO		1,813.8		123.0	3,976.2	22.0	-92.2				
Ca(OH) <sub>2</sub>							222.6				
CaSO <sub>4</sub>							61.5				
Na <sub>2</sub> O				61.5	1,987.9						
Na <sub>2</sub> CO <sub>3</sub>		3,504.3									
NaCl					29.7						
S					1.4						
C <sub>n</sub> H <sub>2n+1</sub>											
Water of Hydration											
Heavy Metals	0.0			37.9	105.9		22.3	15.6			
<b>Total</b>	0.0	5,318.1	0.0	1,127.6	35,371.9	22.0	1,119.5	15.6	0.0	0.0	
<b>Liquids</b>											
H <sub>2</sub> O	0.0								4,965.1		
NaOH									167.0		
NaCl	0.0										
NaNO <sub>3</sub>	0.0										
<b>Total</b>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5,132.1	0.0	
<b>Gases</b>											
H <sub>2</sub> O				26,273.3				28,302.8			30,803.6
N <sub>2</sub>			51,251.4	51,138.6				51,138.6			51,176.7
O <sub>2</sub>			15,769.7	5,667.4				5,667.4			5,554.1
Ar			938.7	938.7				938.7			938.7
CO <sub>2</sub>				10,459.2				10,459.2			10,459.2
SO <sub>2</sub>				104.7				0.0			
NO <sub>x</sub>				125.2				125.2			
NaCl			67,959.7	96,889.4	0.0	0.0	0.0	96,814.2	0.0		98,932.4
<b>TOTAL</b>	0.0	5,318.1	67,959.7	98,017.0	35,371.9	22.0	1,119.5	96,829.9	5,132.1		98,932.4

maintenance problems in the plasma vitrification system, including ductwork corrosion and deposit formation. At plasma melter operating temperatures, much of the NaCl present in the sediment will be vaporized, with a fraction escaping into the offgas system. Heavy salt vapor loading in the offgas ducting may result in deposition on duct walls, and it will accelerate corrosion of the offgas system refractory, as well as increase the dissolved salts loading in the scrubber. NaCl loading in the offgas is large, the scrubber water will rapidly become saturated with sodium chloride, requiring a larger bleed stream to be removed from the gas scrubber water. Since the bleed stream may need to be treated prior to disposal, liquid treatment costs will be lowest when a pretreatment step removes most of the salt.

Removal of NaCl is accomplished by simple rinsing and dewatering process. Fine clay-like sediment is often difficult to filter, and tends to rapidly clog the pores of the filtration medium. Operating experience by Severson Environmental indicates that addition of calcium-based materials or polymers greatly simplifies the process of fine sediment filtration. A filtration aide is therefore added (Stream 4) to agglomerate the fines into larger particles. Since calcium will be added later in the process as a glass matrix modifier, hydrated lime (calcium hydroxide) at a typical concentration of 0.1 lb/gallon is an obvious choice as a filtration aide. Lime added to dewater the sediment accounts for roughly two-thirds of the total calcium oxide required as a flux for vitrification.

Dewatering will be important to any thermal process, since heating excess water represents an unnecessary process cost. The sediment is partially dewatered by processing with a high-throughput filter. Single-stage filtration dewateres the sediment to approximately 60 weight percent solids, removing in excess of 90% of the dissolved salt from the sediment (initially 2 weight percent NaCl). Stream 8 then contains only 0.35% NaCl. If a second-stage filtration is needed or additional washing on the same filter is desired, rinse water (Stream 6) is added to further desalinate the mixture. This process yields a melter feed stream that is once again dewatered to 60% solids, but now contains less than 0.10% NaCl, removing 95% of the chloride. The material balance conservatively assumes that rinsing with two volumes of fresh water is required, and 60% solids result in the dewatered sediment.

The saltwater discharge stream, the filtrate, does not contain contaminant concentrations of any hazardous species of regulatory concern. Analysis of the filtrate from Phase II Pilot Tests indicates the presence of no toxic heavy metals or organics which exceeded free discharge concentrations. The filtrate characteristics are discussed in detail in Section 11. Lime addition for filtration in Phase II did, however, elevate the filtrate water's pH to slightly above 10. A small quantity of an organic acid, such as sulfuric acid, will be used to neutralize the water prior to discharge, or this stream could be blended with other discharge process water to bring the combined pH below 10. It is also notable that dewatering removed

roughly 60% of the total sulfur in the sediment, presumably present as soluble sulfates.

### **12.1.3 Plasma Vitrification**

The composition of the sediment is then adjusted by the addition of fluxes such as soda ash and lime. Addition of these species allows fine tuning of the chemical and physical properties of the glass (e.g., melting point, viscosity, and thermal expansion coefficient of the final glass product). The blended feed (Streams 8 plus 10) is then injected into the mixing duct (known as a tuyere) with a ram or high pressure injection pump.

On contact with the intense heat of the plasma plume, the fine sediment-flux mixture is rapidly heated. The plasma plume consists of a jet of air which has been superheated to temperatures approaching 5000°C by passage through a DC arc. Additional air is injected into the tuyere, dropping the temperature and extending the lifetime of the tuyere refractory. On contact with this superheated air stream, the fine sediment particles are heated first to the point where the water content is flashed to steam. Calcination temperatures are then reached, sodium and calcium carbonate or hydroxide fluxes are dissociated to form Na<sub>2</sub>O and CaO, and hydrated mineral species are reduced to anhydrous oxides. Finally, the metal oxide mixture is heated to melting temperatures where a homogeneous molten glass is formed.

Because of the extremely high temperatures and vigorous mixing conditions (assisted by the explosive evaporation of the sediment's moisture content), the heat transfer coefficients in the tuyere zone are extremely large, and complete melting of refractory oxide particles takes place in time scales on the order of 10 to 50 milliseconds. A typical mixing temperature in the melting tuyere is 2200 to 2600°C, whereas the highest melting species in the sediment fuses at only 2045°C (alumina). Complete melting, therefore, occurs before the feed leaves the tuyere. Rapid melting is enhanced by the small particle size of the sediment, and the vigorous mixing and intense thermal radiation in the tuyere. Phase II Pilot tests confirm these assumptions. The product glass from Phase II was homogeneously vitrified and contained negligible quantities of unmelted sediment material, despite the short tuyere residence time.

The liquid metal oxide mixture then pours into the melter's crucible zone at the exit of the tuyere. The melt accumulates there for a residence time characteristic of the design pool depth and product throughput. In Phase II vitrification tests, the total residence time in the melter was less than 30 minutes, as compared with many hours in a large commercial glassmaking tank. The Plasma Melter product was nevertheless well vitrified and homogeneous, further evidence of the extremely rapid thermal processing taking place in the tuyere.

#### **12.1.4 Glass Product Manufacture**

The molten glass/slag product is extracted via a bottom drain and collected. The flowsheet in Figure 12.1 assumes molten glass is water quenched to form a granular aggregate (Stream 13). In actual production processing, the molten product can be directly quenched into water to produce a shattered aggregate material, or collected for fabrication of alternate products.

Two principal high-value glass product types are currently being considered, fiber glass product and a manufactured tile product. If fiber glass is to be manufactured, the molten glass will be directly poured into fiberizing equipment; additional "fining" time in a heated container would probably be required to assure 100% melting of all sediment solids which could block the fine nozzles used in fiber glass spinning, and to ensure complete melt homogeneity. Glass tile manufacture would occur by engineered water quenching the glass to make a controlled size of aggregate. This glass aggregate would then be combined with pigments and baked in tile molds to produce the final product.

Other final product glass manufacturing options include:

- Spinning into crude fibers with rotating wheels for rock wool insulation;
- Spinning into fibers with centrifugal drum spinners for fiberglass insulation;
- Granulating or prilling to form roofing granules for asphalt shingles;
- Coarse quenching to form construction aggregate for roadbed or cinder block;
- Fine quenching to form sandblasting grit ("Black Beauty");
- Crushing to form cullet for the manufacture of glass beads or other glass products; and
- Quenching to form filler material for artificial onyx resin, such as that used in the manufacture of bathtubs.

Each of these product options produces a material having a different value, market demand, and production overhead.

#### **12.1.5 Gas Cleaning**

The offgas cleaning system will be designed to remove nitrogen oxides, sulfur oxides, and any volatile metal components from the gas stream. The offgas handling system proposed for plant operation is comprised of components well established for handling contaminated offgases -- (1) a quench system, (2) a high temperature sulfur adsorption system, (3) a high efficiency scrubber and water recirculation system, (4) a separator demister, (5) a heat exchanger, (6) offgas

particulate and mist emission control filters, and (7) regenerative blowers to maintain a negative pressure within the vitrification melter.

Lime injection is an industry standard for removal of sulfur from the effluent of coal-fired power plants, and can be readily applied here. The high temperatures of the plasma offgas stream will prevent condensation of Hg and heavy metal chloride vapors with the CaSO<sub>4</sub>, so that this waste stream should be minimally contaminated.

Most of the metal oxide components of the sediment will rapidly be incorporated into the glassy melt. Some fraction of the more volatile heavy metals (e.g., Cd, Pb, Cr, As, and especially Hg), as well as sulfur and nitrogen oxides, will report to the offgas stream and leave the melter. The partitioning of these metals during plasma vitrification was measured in the Phase II Pilot Tests. Volatile metal removal from this offgas is accomplished by:

- partial quenching to reduce the temperature;
- lime injection to absorb sulfur dioxide;
- hot gas filtration to collect and remove calcium sulfate formed by sulfur gettering;
- high-efficiency liquid scrubbing to complete the gas quenching and to remove and collect heavy metals and nitrogen oxides; and finally
- low-temperature final filtration to eliminate entrained mist.

Phase II Pilot Plant testing demonstrated that complete (99.9999%) destruction of organics occurs in the melter. No downstream thermal treatment of the offgas for final organic destruction will not be necessary.

#### **12.1.6 Scrubber Water Treatment**

The scrubber liquor is circulated through a heat exchanger to remove excess heat, and makeup water is continuously added to account for water stripped out as steam by the hot offgases. Volatile heavy metals will gradually accumulate in the recirculating scrubber water, and may render this stream a hazardous waste. Two options exist for dealing with this water stream:

##### **1. High-Throughput Option**

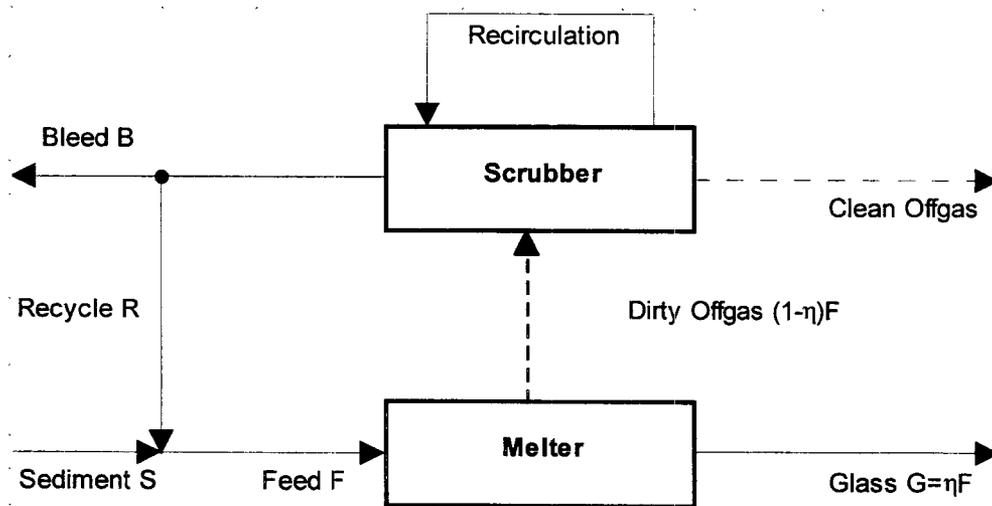
Discharge the water continuously with relatively low residence time in the system, such that the concentrations of all species of concern are low enough to satisfy all water discharge regulations. Treatment costs are minimized. However, the volume of water consumed is higher, and the heavy metal contaminants from the sediment are returned to the environment.

## 2. Low-Throughput Option

Recirculate the water for a long period of time to maximize the accumulation, and then treat the water to remove and sequester the contaminant metals. The volume of makeup water is minimized and the contaminants are removed from the environment, but additional treatment costs are incurred.

In the low-throughput option, it is economically desirable to maximize the fraction of the metals retained in the glass. A fraction of the scrubber liquor may be continuously withdrawn and returned to the melting tuyere to accomplish this end. As shown in Figure 12.2, as the heavy metal concentrations build up in the recirculating scrubber solution, eventually each will attain a concentration such that the fractional retention  $\eta$  in the glass, multiplied by the feed rate of that metal  $F$  in the mixed sediment plus recycle feed stream ( $S + R$ ), is equal to the accumulation of that metal in the glass  $G$ . If no bleed  $B$  is removed from the scrubber, the concentration of metal will build up in the system until the recycle rate  $R$  is equal to  $(1-\eta)S/\eta$ .

Not all species can be incorporated into glass; in particular, the solubilities of mercury and chloride are very low. As a result, these species will accumulate to very high concentrations in a closed system with no bleed. A continuous bleed is therefore removed for treatment to prevent continuous accumulation of contaminants having low glass solubility. The total volume of the recycle stream is dominated by chloride, which is present at the highest concentration in the feed, and is known to have a low glass retention (measured at approximately 10%



Flowrate Variables Refer to Massflow of Specific Heavy Metal

Figure 12.2 Accumulation of Volatile Metals in Scrubber System

during vitrification testing). At least enough bleed stream must be removed to prevent the scrubber water from exceeding the solubility of NaCl. This retention efficiency sets the volume of the recycle stream reported in the material balance, where the recycle water flowrate is roughly two-thirds of the water flow in the partially dewatered feed.

No recycle was used during Phase II pilot plant testing, and there is no indication from the Phase II data that scrubber water recycle will be needed for good metal incorporation in the product glass.

The bleed stream from the scrubber water will need to be treated to remove heavy metals that are too volatile to be captured in the glass melt. Both the Phase II Pilot Test results and projections of metal levels in this stream indicate the need for treatment. The volumetric flowrate of the scrubber bleed stream shown in Figure 12.1 (Stream 19) is only roughly 1.42 gallons/minute (2,850 tons/yr), based on maintaining the scrubber water at 20% of the saturation concentration of NaCl. The bleed is roughly 0.5% of the scrubber system makeup water.

The Phase II Pilot Test scrubber water was treated by a proprietary precipitation and stabilization process. The treatment process successfully cleaned the water for discharge and generated a stabilized nonhazardous solid waste that contained all hazardous metals. Alternative treatment approaches include high-efficiency chelating ion exchange resins.

#### **12.1.7 Optimum Water Content for Dredged Materials**

Commercial sediment decontamination will benefit from dredging which minimizes water content because the salt concentration fed to the decontamination equipment will be reduced if the sediment contains less water. Lower salt content results in (1) improved system operability due to reduced risk of salt deposits in the offgas system, (2) lower maintenance costs due to improved refractory lifetime, and (3) reduced size of the scrubber bleed stream, providing a smaller and more concentrated heavy metal stream for water treatment.

The decontamination process will need to be designed to water rinse and then dewater sediment, regardless of the dredged materials water content. The sediment is water rinsed in order to reduce the salt loadings to the plasma melter. If the dredged material contains less water and, therefore, less salt, our rinsing step will be more effective. This will reduce the plasma plant's maintenance and operating cost because less salt will be carried into the plasma system, corroding the materials of construction, and less salt will also build up in the recycle stream, and therefore, the recycle purge stream will be smaller, reducing the operating cost of the plant.

The optimum water content for the dredged material is, therefore, the lowest content obtainable because the lower the sea water content, the less salt will be present in the sediment. Obviously, the integrated treatment train will be designed to optimize the overall system economics. Any increases in dredging cost for

reducing the raw sediment's water content will need to be balanced by the cost reduction in the decontamination processing steps.

For the purposes of developing this design, we assume that the dredged sediment will contain about 30% solids, as did the Newtown Creek samples, and the anticipated pretreatment system is designed to remove NaCl from sediments having roughly this sea water content. The economically optimum pretreatment system will depend on the exact configuration of the plant and the cost basis for the plant such as the site's cost of electricity. Using our current assumed cost basis, for every weight percent increase in solids content achieved in dewatering, the processing cost is decreased by about \$1/ton. In other words, changing the plasma feed material from a 50 weight percent solids material to a 60 weight percent solids material, decreases the operating cost by \$10/ton. Notice that the dewatering system must work on rinsed sediment, so water will be added to any as-dredged sediment.

#### **12.1.8 Intellectual Property**

There will be no licensing fees associated with the scaleup of the process. Westinghouse maintains twenty four patents on the plasma torch and plasma processing technology. Additional patent disclosures and applications are pending, including the application of plasma technology to sediments and related wastes.

The know-how developed by Westinghouse to successfully apply plasma technology to the processing of materials for resource recovery, destruction, or volume reduction to meet specific application needs is a primary intellectual property resource.

### **12.2 ENERGY BALANCE**

Table 12.3 summarizes the energy balance for the 100,000 cy/yr process, using the best pilot energy requirements as a basis. As discussed in Section 10, that production-scale (100,000 cy/year) and full-scale (500,000 cy/year) systems will use less energy than the pilot test unit, but we will use the pilot results as a conservative basis for the plant's energy requirements. The total plant energy consumption is 16.7 MW. Nearly 40% of the total energy is directed into heating and melting of the solids, while most of the balance is consumed by evaporating and superheating water. Sediment hydrocarbons provide a heating value equivalent to 5 MWe.

Torch efficiency, air flow, heat losses, and melting energy are based on plasma system commercial experience applied to the sediment application. Although the Westinghouse plasma torch is rated in excess of 2000 kW, a conservative 1700 kW rating is assumed for extended electrode lifetime.

Table 12.3 Energy Balance for Plasma Process

Plant Capacity	100,000 cy/yr (106,000 ton/yr)
As-Dredged Sediment Solids Content	33 weight percent
Melter Feed Solids Content	60 weight percent
Flowrate per Melter Tuyere	50 lb/minute
Number of Melter Tuyeres	10
Individual Torch Operating Power	1700 kW
Plasma Torch System Efficiency	90%
Tuyere Mixing Temperature	1800°C
Total Power Requirement	16,750 kW
Power from Sediment Hydrocarbon Combustion	5000 kW
Vaporization of Water	1010 kW (6%)
Heating of Product Gases	7540 kW (45%)
Heating and Melting of Oxides	6530 kW (39%)
Plasma System Heat Losses	1670 kW (10%)

A feed solids content of 60% is assumed, which will be achieved by dewatering sediment to 56% solids and then adding glass fluxes. These estimates are consistent with actual pilot test performance. The tuyere operating temperature at thermal equilibrium is 1800°C, which is 400°C above the glass melting temperature and accounts for the extremely rapid heat transfer.

### 12.3 PLANT CONFIGURATION

We assume that the current design concept is based on a fixed based sediment processing facility. Westinghouse is also able to develop a design for a barge-mounted system for plasma vitrification of the sediment, if desired. The scope of operations performed on any barge mounted system and the sediment throughput in a barge mounted system would need to meet the practically size constraints of any such unit.

The plant configuration for the a production-scale (100,000 cy/year) design will consist of one plasma melter unit with ten multiple torches, along with the associated pretreatment and gas cleaning equipment. The melter will consists of a vertical circular shaft with a refractory-lined crucible bottom. The ten melting tuyeres will be arranged radially around the perimeter, each feeding into the common crucible. Figure 12.3 shows a representative configuration for the plasma melter with multiple torches.

The full-scale (500,000 cy/year) system will be composed of five 100,000 cy/year processing trains. The material balance shown in Section 12.1 indicates that the 100,000 cy/yr plant would produce molten product at a flowrate of 8,800 lb/hr. Pilot vitrification tests generated from 600 to 820 lb/hr of glass with a single torch; approximately ten torches will be required to meet the required throughput. Ten torches will be arranged on a single melter island. Westinghouse has a similar melter island design in commercial operation at the General Motors Corporation plant in Defiance, Ohio. This plasma metal melter operates at a throughput of 90 tons/hr in a single melter operating with eight torch assemblies; the melter has an overall melter diameter of four meters.

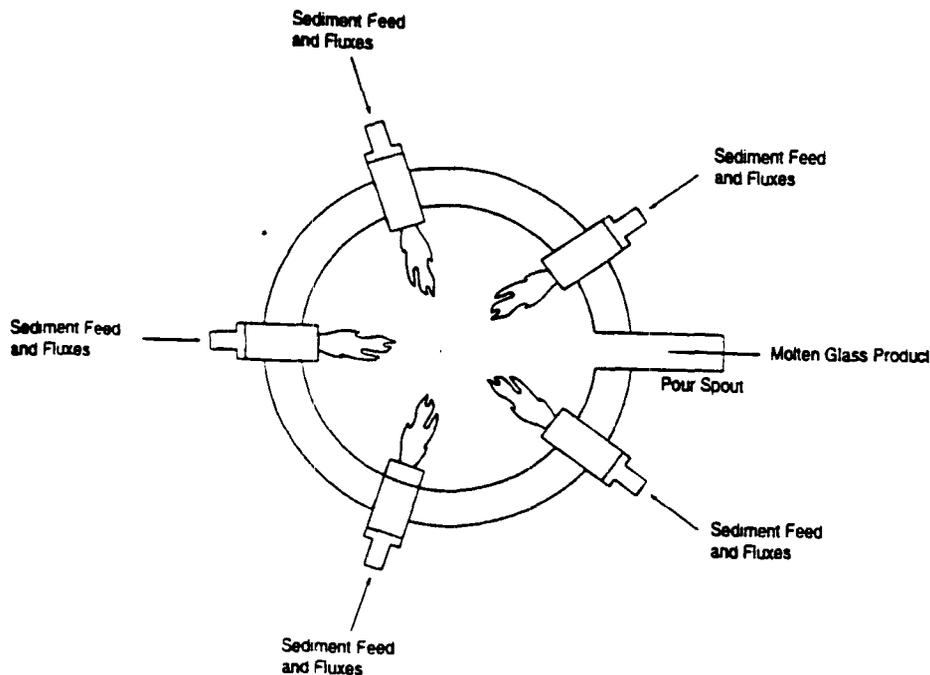


Figure 12.3 Melter Island Configuration

One or two product extraction spouts would remove molten glass product from the melter. This material may fall directly into a water bath where it would shatter into a gravel-like material suitable for use as aggregate, or additional processing operations could convert the molten glass into commercial glass products.

#### 12.4 PRODUCTION REQUIREMENTS

The site, utility, and personnel requirements for the production-scale (100,000 cy/yr) and full-scale (500,000 cy/yr) operations are presented in this section.

### 12.4.1 Site Requirements

A two-acre site size is envisioned for the production-scale plant. Ten acres will be required for the 500,000 cy/year full-scale plant. These estimates include sediment preprocessing operations as well as integrating plasma vitrification process with a simple glass manufacturing operation. A preliminary plant layout is being developed in the preliminary design phase.

### 12.4.2 Utility Requirements

The utility requirements for the production-scale facility, presented in Table 12.4, are based on the material balances presented in Section 12.1.

Table 12.4 Plant Utility Requirements

Utility	100,000 cy/year	500,000 cy/year
Electrical Power	16.7 MWe	84 MWe
Water Usage		
Process Water:	40 gpm	200 gpm
Scrubber Makeup Water	12 gpm	60 gpm
Quench Makeup Water	18 gpm	90 gpm
Recycled Water:		
Torch Cooling Water	750 gpm	3750 gpm
Melter Cooling Water	280 gpm	1400 gpm
Compressed Air (Generated On-Site)	4,000 scfm	20,000 scfm
Glass Former	8300 ton/year	41,500 ton/year
Raw Sediment	100,000 cy/year	500,000 cy/year
Glass Product	35,400 ton/year	177,000 tons/year

### 12.4.3 Personnel Requirements

Personnel requirements identified for each shift of plant operations are shown in Table 12.5.

Table 12.5 Plant Labor Requirements

Position	Number Needed per Shift	
	100,000 cy/year	500,000 cy/year
Yard Operator	2	4
Control Room Operator	1	1
Maintenance	1	1
Supervisor	1	1

## 12.5 ESTIMATED SEDIMENT PROCESSING COST

This section presents an estimated costs for plasma decontamination plant. In order to provide accurate cost estimates, a preliminary design is required. The preliminary design will specify design parameters such as the operation requirements (e.g., round the clock, year round), system design basis (e.g., fixed versus shipboard), and sediment supply characteristics (e.g., water content, oil content). Cost comparisons for varied treatment systems also need to be based on standard project scopes (e.g., dredging, waste treatment, waste stream disposal) and standard assumptions as to important factors such as labor and utility rates.

The capital cost for a 500,000 cy/yr sediment decontamination plant is estimated at \$45 million. This capital estimate is based on scaling the costs of similar commercial plasma facilities. At this time, the capital cost does not include capital requirements for glass manufacturing. Once the plant's preliminary design is complete, a reasonably accurate (10 to 20% accurate) plant capital cost will be defined.

Table 12.6 summarizes the operating costs of a 500,000 cy/yr sediment processing facility, showing all elements of operating costs (e.g., materials, utilities, waste disposal, labor). The cost is based on the material balance shown in Tables 12.1 and 12.2, scaled to a 500,000cy/yr facility. Plant energy requirements used in the operating costs are conservatively based on pilot test data. Price data are taken from catalogs (chemical prices) or actual utility quotations in the New York Harbor area (electricity rate of \$0.05/kWh).

Many parametric evaluations could be performed on the operating cost. Table 12.5 shows parametric ranges for three key cost variables.

- Cost of electricity, ranging from \$0.03 to 0.05 /kWhr

Electrical cost is the single largest element for the operating cost. We have used a conservative electrical requirement. The demonstration phase will show a reduction in energy requirements for the decontamination plant.

- Sediment tipping fee, ranging from \$10 to 50/cy

Tipping fees will depend on the need for dredging and the availability of other sediment disposal options.

- Glass product value, ranging from \$20 to 500/ton.

The ability to manufacture a high quality glass product can make the decontamination plant profitable. Glass products have values between \$20/ton for aggregate to over \$500/ton for high value glass fibers or glass tile.

Table 12.6 Operating Cost Estimate  
 Capital Cost Estimate: \$45 million for 500,000 cy/year plant Break-Even Cost for Glass Product \$138 to 327/ton

Category	Item	Unit	Unit Cost, \$	Units/year	Annual Cost, \$/year	Unit Cost, \$/cu yd
Materials	Soda Ash	ton	92	19,000	1,748,000	3.5
	Lime, quicklime	ton	60	22,500	1,350,000	2.7
	Lime, hydrated	ton	70	2800	196,000	0.39
	Precipitant, Water Treatment	ton	3200	15.6	49,920	0.1
Utilities	Electricity	kWhr	0.03 to 0.05	672 MM <sup>a</sup>	20.1 to 33.6 MM	40.3 to 67.2
	Water	1000 gal	1	500,000	500,000	1
Disposal Costs	CaSO <sub>4</sub>	ton	50	6150	307,000	0.61
	Oversize Material	ton	20	5800	116,000	0.23
	Rinse Water	1000 gal	0	261,000	0	0
	Scrubber Water	1000 gal	30	3700	111,000	0.22
	Stabilized Sludge with Precipitated Metals	ton	50	460	23,000	0.05
Labor @8760 hrs/year	Yard Operators (12)	hr	27	35,040	946,080	1.90
	Control Room (3)	hr	27	8760	236,520	0.47
	Mechanics (3)	hr	36	8760	315,360	0.63
	Shift Supervisors (3)	hr	36	8760	315,360	0.63
	Site Manager	hr	50	2920	146,500	0.29
	<b>Total Labor</b>	<b>hr</b>		<b>63,510</b>	<b>1,959,820</b>	<b>3.92</b>
Operations	Maintenance <sup>b</sup>	\$			2,250,000	4.5
	<b>Total Operating Cost</b>	<b>\$</b>			<b>28.7 to 44.2 MM</b>	<b>57.5 to 84.4</b>
Glass Manufacturing Levelized Capital-Based Costs <sup>c</sup>	Estimate for Product	ton	80	177,000	14,000,000	28
	500,000 cy/year plant	M\$	45	1	6,750,000 <sup>a</sup>	13.5
	<b>Total Cost</b>				<b>49.5 to 63.0 MM</b>	<b>99 to 126</b>
Credits	Sediment Tipping Fee	ton	20	500,000	-10 to -50MM	-10 to -50
	Product Sale	ton	20 to 500	177,000	-3.5 to - 88.5 MM	-7 to -180
<b>Net Profit or Loss</b>				<b>54 to -64 MM</b>	<b>109 to -130</b>	

a) 84 MWe required

b) 5% of capital

c) 15% per year with 20 year plant life

Using the current plant assumptions and cost basis, the processing cost for as-dredged sediment ranges from \$58 to 84/ton depending on the cost of electricity. To this operating cost, an estimated \$28/ton of feed sediment for glass manufacturing (\$80/ton glass manufactured) is added, along with levelized capital-based costs of \$13.5/ton for \$45MM capital investment over a 20 year plant life. Including glass manufacturing and plant capital; the processing expenses are \$99 to 126/ton.

The decontamination operation will have two major credits, product glass sale and a tipping fee for disposing of dredged sediment. A wide range in credit values will exist until we specify a particular glass product and develop specific plant tipping fees. The glass product value obviously controls plant economics. If a high value product can be produced, the plant can have net revenues of up to \$130/ton of feed sediment. The break-even glass product value for which the plant turns a profit ranges from \$138 to 327/ton, depending on the cost of electricity and the sediment tipping fee

## Appendix A - Brookhaven National Laboratory Sample Analyses

The following are chemical and physical analyses of solids and liquid samples generated during Phase II Demonstration Test 3.

<b>Sample Log</b>	A-2
<b>Sediment, Filter Cake, and Plasma Feed</b>	A-3
Gross Physico-Chemical Properties	A-3
Polychlorinated Biphenyls	A-4
Semivolatile Organic Carbon Compounds	A-5
Dioxins and Furans	A-7
RCRA Metals	A-8
<b>Quenched Glass</b>	A-9
Gross Physico-Chemical Properties	A-9
Polychlorinated Biphenyls	A-10
Semivolatile Organic Carbon Compounds	A-11
Dioxins and Furans	A-13
RCRA Metals	A-14
Polychlorinated Biphenyls (TCLP)	A-15
Semivolatile Organic Carbon (TCLP)	A-16
Dioxins and Furans (TCLP)	A-18
RCRA Metals (TCLP)	A-19
<b>Flux Additives (Lime and Soda Ash)</b>	A-20
RCRA Metals	A-20
<b>Filtrate, Rinse Water, and Scrubber Water</b>	A-21
Gross Physico-Chemical Properties	A-21
Polychlorinated Biphenyls	A-22
Semivolatile Organic Carbon Compounds	A-23
Dioxins and Furans	A-25
RCRA Metals	A-26

Westinghouse Pilot		As of 29May97	
Report#	Entered?	Analysis	Samples
40473A	Y	SVOC's	WP-D3-07-01B WP-03-4B-02B WP-R1-2A-01B
40473B	Y	PCB's	WP-R1-2A-02B Rinse Water
40473Br1	Y	PCB's	WP-D3-07-04B WP-03-4B-05B
40473C	Y	Dioxin's and Furans	WP-D3-07-05B WP-03-4B-06B WP-R1-2A-03B
40473D	Y	Metals	WP-D3-07-07B WP-03-4B-08B WP-R1-2A-04B
40473E	Y	SVOC's	WP-R1-01-01B WP-D4-08-15W WP-03-01-02B
40473Fr1	Y	PCB's	WP-R1-01-01B WP-D4-08-15W WP-03-01-02B WV-03-01-01B
40473G	Y	Dioxin's and Furans	WP-R1-01-01B WP-D4-08-15W WP-03-01-02B WV-03-01-01B
40473H	Y	Metals	WP-R1-01-01B WP-D1-05-01B WP-D4-08-15W WP-M1-09-01B WP-M1-10-01B WV-03-01-01B WV-03-01-02B
40473I	Y	Metals(TCLP)	WV-03-02-01B WV-03-02-02B WV-03-02-09B
40473J	Y	SVOC's(TCLP)	WV-03-02-01B WV-03-02-02B WV-03-02-09B
40473K	Y	PCB's (TCLP)	WV-03-02-01B WV-03-02-02B WV-03-02-09B
40473L	Y	Dioxin's and Furans(	WV-03-02-01B WV-03-02-02B WV-03-02-09B
40473M	Y	Subcontract Data	
40473N	Y	Metals	WV-03-02-01B WV=03-02-09B Bulk Data on Quenched Glass
40473Or1	Y	Dioxins/Furans	WV-03-02-01B WV=03-02-09B Bulk Data on Quenched Glass
40473P	Y	PCB's	WV-03-02-01B WV=03-02-09B Bulk Data on Quenched Glass
40473Q	Y	SVOC's	WV-03-02-01B WV=03-02-09B Bulk Data on Quenched Glass
40473R	Y	Metals	WV-03-04A-07B Final Scrubber Water
40473S	Y	Dioxins/Furans	WV-03-04A-07B Final Scrubber Water
40473T	Y	PCB's	WV-03-04A-07B Final Scrubber Water
40473U	Y	SVOC's	WV-03-04A-07B Final Scrubber Water
40473W	Y	Metals(TCLP addition	WV-03-02-01B WV-03-02-09B WV-03-02-02B

	WP-R1-01-01B As Dredged	WP-D4-08-15W Filter Cake	WV-03-01-01B Plasma Feed	WV-03-01-02B Plasma Feed	WP-R1-01-01B Duplicate	WP-R1-01-01B Duplicate
<b>Gross Physico-Chemical Properties</b>						
<b>Particle size</b>						
(% Dry Weight)						
ASTM D422 (Mod)						
Medium gravel > 4.75 mm	0.00	0.00	0.00	0.00	0.00	0.00
Fine gravel 2-4.75	0.02	0.06	0.09	0.00	0.32	0.41
V. coarse sand 0.85-2	1.02	0.19	0.50	0.24	1.43	1.57
Coarse sand 0.425-0.85	2.27	0.58	3.24	1.94	1.96	2.00
Medium sand 0.24-0.425	4.03	1.56	5.82	7.84	4.25	4.96
Fine sand 0.106-0.24	10.5	5.69	6.28	9.44	10.4	11.2
V. fine sand 0.075-0.106	2.85	2.59	1.99	1.94	3.22	3.18
Clay < 0.0039	34.3	40.1	50.0	49.0	34.6	35.3
Silt 0.0039-0.0625	44.8	48.3	36.7	32.9	44.3	43.5
<b>pH</b>						
EPA 9045A pH Units	7.73	6.83	12.67	12.63	7.60	
<b>Solids (total)</b>						
EPA 160.3 % dry wt.	37.1	50.9	52.1	51.8		
<b>Sulfides (total)</b>						
EPA 9030M mg/Kg dry wt.	7900	3.7	2.7	1.0	6400	
<b>Organic Carbon (total)</b>						
ASTM D4129-82M % dry wt.	8.84	8.46	6.33	6.22	8.60	
<b>TRPH</b>						
EPA 3550A/8015 Mod. mg/Kg Dry wt.	18300	14000	11200	12000		

Report 40473Fr1	WP-R1-01-01B As Dredged	WP-D4-08-15W Filter Cake	WV-03-01-01B Plasma Feed	WV-03-01-02B Plasma Feed	WP-R1-01-01B Duplicate	WP-R1-01-01B Duplicate
<b>Polychlorinated Biphenyls</b>						
(ug/Kg dry weight)						
EPA MM680/HRGC/MS						
Mono-PCB data were not available for these samples						
Due to loss of internal standards						
2-Mono Congener # 1	NA	NA	NA	NA	NA	NA
44'-Di # 15	73.9	53.6	55.3	52.0	52.0	52.0
244'-Tri # 28	411 PR	323 PR	321 PR	340 PR	340 PR	340 PR
22'55'-Tetra # 52	231	195	218	11.2	11.2	11.2
33'44'-Tetra # 77	16.2	12.3	13.6	11.1	11.1	11.1
2344'5'-Penta # 118	6.0	6.6	4.8	4.6	4.6	4.6
233'44'-Penta # 105	72.3	62.8	64.4	62.8	62.8	62.8
33'44'5'-Penta # 126	0.84	0.76	0.83	0.72	0.72	0.72
233'44'5'-Hexa # 156	19.6	13.8	16.4	16.7	16.7	16.7
33'44'55'-Hexa # 169	0.3	0.5	0.6	0.6	0.6	0.6
22'344'55'-Hepta # 180	109	88.6	88.0	96.8	96.8	96.8
22'33'44'55'-Octa # 194	24.5	22.4	22.2	24.8	24.8	24.8
22'33'44'55'6'-Nona # 206	18.1	16.2	20.9	18.4	18.4	18.4
Deca # 209	15.2	14.4	16.1	17.1	17.1	17.1
PR=Poorly Resolved Q=Quantitative Interference						
<b>PCB Totals:</b>						
-Mono	NA	NA	NA	NA	NA	NA
-Di	692	746	406	344	344	344
-Tri	1077	848	818	870	870	870
-Tetra	1739	1391	1530	1507	1507	1507
-Penta	1562	1294	1396	1424	1424	1424
-Hexa	1288	1091	1298	1379	1379	1379
-Hepta	471	413	427	467	467	467
-Octa	135 Q	123 Q	164	178	178	178
-Nona	33.1 Q	31.6 Q	43.9 Q	36.8 Q	36.8 Q	36.8 Q

Feed Materials

Report	WP-R1-01-01B As Dredged	WP-D4-08-15W Filter Cake	WV-03-01-01B Plasma Feed	WV-03-01-02B Plasma Feed	WP-R1-01-01B Duplicate	WP-R1-01-01B Duplicate
40473E						
<b>SVOC's - Page 1 of 2</b>	No diskette supplied by Triangle Labs -					
EPA 8270A (ug/kg dry weight)	only "Hits" listed - no data means sample below detection					
Phenol			946.41 J	971.4 J		
bis(2-Chloroethyl)ether						
2-Chlorophenol						
1,3-Dichlorobenzene						
1,4-Dichlorobenzene						
1,2-Dichlorobenzene						
Benzyl alcohol						
2,2'-oxybis(1-Chloropropane)						
2-Methylphenol						
3/4-Methylphenol						
N-Nitroso-di-n-propylamine						
Hexachloroethane						
Nitrobenzene						
Isophorone						
2-Nitrophenol						
2,4-Dimethylphenol						
bis(2-Chloroethoxy)methane						
Benzoic acid						
2,4-Dichlorophenol						
1,2,4-Trichlorobenzene						
Naphthalene	2204.08 J	1577.18 J	2791.58 J	2688.6 J		
4-Chloroaniline						
Hexachlorobutadiene						
4-Chloro-3-methylphenol						
2-Methylnaphthalene	1969.53 J	998.09 J	4311.51 J	4705.82 J		
Hexachlorocyclopentadiene						
2,4,6-Trichlorophenol						
2,4,5-Trichlorophenol						
2-Chloronaphthalene						
2-Nitroaniline						
Dimethylphthalate						
2,6-Dinitrotoluene						
2,4-Dinitrotoluene						

J=Below Quantitation Limit

Feed Materials

	WP-R1-01-01B As Dredged	WP-D4-08-15W Filter Cake	WV-03-01-01B Plasma Feed	WV-03-01-02B Plasma Feed	WP-R1-01-01B Duplicate	WP-R1-01-01B Duplicate
<b>SVOC's - Page 2 of 2</b>						
EPA 8270A (ug/kg dry weight)						
Acenaphthylene	2065.19 J	2946.82 J	2522.09 J	2894.64 J		
3-Nitroaniline				5895.75 J		
Acenaphthene	2421.12 J	4256.82 J	5108.57 J			
2,4-Dinitrophenol						
4-Nitrophenol						
Dibenzofuran						
Diethylphthalate						
4-Chlorophenyl-phenylether						
Fluorene	2995.7 J	5431.18 J	7618.70	8591.62		
4-Nitroaniline						
4,6-Dinitro-2-methylphenol						
N-Nitrosodiphenylamine						
4-Bromophenyl-phenylether						
Hexachlorobenzene						
Pentachlorophenol						
Phenanthrene	16385.75 B	32521.9 B	37875.39 B	43050.98 B		
Anthracene	7724.29 J	10936.02	11110.74	13139.40		
Di-n-butyl phthalate	461.68 BJ					
Fluoranthene	19698.35 B	36086.89 B	29973.72 J	32328.91 B		
Pyrene	16100.49 B	27074.00 B	22043.31 B	26742.65 B		
Butylbenzylphthalate	1414.55 J	849.08 J	2092.39 J	1138.03 J		
3,3'-Dichlorobenzidine						
bis-2-ethylhexylphthalate	123032.22 B	33045.00 B	44504.62 B	53595.55 B		
Benzo(a)anthracene	7187.27 J	10960.68	9881.27	11496.83		
Chrysene	8755.63 J	12100.33	10289.20	12738.96		
Di-n-octylphthalate						
Benzo(b)fluoranthene	7205.97 J	11404.31	7014.08	11727.13		
Benzo(k)fluoranthene	3098.77 J	4599.89 J	2928.4 J	4738.56 J		
Benzo(a)pyrene	5294.35 J	8210.67	6172.75 J	7989.50		
Indeno(1,2,3-cd)pyrene	584.37 J	606.01 J	669.1 J			
Dibenz(a,h)anthracene		167.34 J	296.74 J			
Benzo(g,h,i)perylene		665.77 J	600.2 J	691.19 J		
Benzo(e)pyrene	4084.8 J	5860.59 J	4405.15 J	5751.29 J		
Perylene	1357.81 J	1890.37 J	1392.82 J	1930.08 J		

Report 40473G Dioxins and Furans (ng/kg dry weight) EPA 8290	WP-R1-01-01B	WP-D4-08-15W	WV-03-01-01B	WV-03-01-02B	WP-R1-01-01B	WP-R1-01-01B
	As Dredged	Filter Cake	Plasma Feed	Plasma Feed	Duplicate	Duplicate
	"PR" means poorly resolved peak					
2378-TCDD	19.0	18.3	18.9	6.8		
12378-PeCDD	24.7	34.7	33.2	10.8		
123478-HxCDD	30.3	40.4	47.8	14.5		
123678-HxCDD	76.9	98.1	134	44.5		
123789-HxCDD	74.0 PR	96.6 PR	115 PR	39.1 PR		
1234678-HpCDD	1275	1570	2993	901		
OCDD	9655	11980	22301	6820		
2378-TCDF	197	231	243	96.4		
12378-PeCDF	165	195	198	76.6		
23478-PeCDF	85.0	95.0	106.2	41.4		
123478-HxCDF	1060 PR	1050 PR	1200 PR	501 PR		
123678-HxCDF	339	362	374	143		
234678-HxCDF	117	142	148	55.8		
123789-HxCDF	4.2183 PR	5.1 PR	4.3 PR	2 PR		
1234678-HpCDF	3600	3280	3220	1290		
1234789-HpCDF	83.2	75.2	96.2	35.4		
OCDF	3920	3550	3350	1230		
Totals: Dioxins						
-TCDD	191	224	243	96.8		
-PeCDD	187	266	351	88.2		
-HxCDD	791	982	1670	486		
-HpCDD	2690	3150	8870	2350		
Totals: Furans						
-TCDF	1760	2090 E	2070 E	922.8226 E		
-PeCDF	2090 E	2430 E	2570 E	1020 E		
-HxCDF	3810	3940	4220	1700		
-HpCDF	4730	4150	4470	1810		

	WP-R1-01-01B As Dredged	WP-D4-08-16W Filter Cake	WV-03-01-01B Plasma Feed	WV-03-01-02B Plasma Feed	WP-R1-01-01B Duplicate	WP-R1-01-01B Duplicate
Report 40473H						
Metals (blanks all < 3 ppb)						
(mg/kg dry weight)						
EPA 6010A & EPA 7471						
Ag	16.0	13.4	13.7	12.9	15.6	
As	30.6	38.9	30.8	29.7	30.1	
Be	0.53	0.39	0.32	0.37	0.57	
Cd	33.0	30.6	24.9	23.6	33.7	
Cr	342	357	292	273	348	
Cu	1160	1020	809	783	1130	
Ni	252	235	184	173	246	
Pb	587	640	516	485	602	
Sb	2.10	1.54	1.30	1.48	2.27	
Se	4.92	5.39	3.57	2.90	4.33	
Tl	2.63	1.92	1.62	1.84	2.84	
Zn	1690	1680	1380	1310	1700	
Hg (total)	2.08	3.09	2.57	2.50		

Data Entered On: By: R.J.Wilke					
Checked: 6May97					
Data Legend:					
Normal Type = Below Detection Limit					
<b>Bold Type = Valid Data</b>					
<i>Italics = Estimated Maximum Possible Concentration</i>					
	WV-03-02-01B	WV-03-02-02B	WV-03-02-09B		
	Quenched Glass	Quenched Glass	Quenched Glass		
<b>Gross Physico-Chemical Properties</b>					
<b>Particle size</b>					
(% Dry Weight)					
ASTM D422 (Mod)					
Medium gravel	> 4.75 mm				
Fine gravel	2-4.75				
V. coarse sand	0.85-2				
Coarse sand	0.425-0.85				
Medium sand	0.24-0.425				
Fine sand	0.106-0.24				
V. fine sand	0.075-0.106				
Clay	< 0.0039				
Silt	0.0039-0.0625				
<b>pH</b>					
EPA 9045A	pH Units				
<b>Solids (total)</b>					
EPA 160.3	% dry wt.	98.3	99.3	95.9	
<b>Sulfides (total)</b>					
EPA 9030M	mg/Kg dry wt.				
<b>Organic carbon (total)</b>					
ASTM D4129-82M	% dry wt.				
<b>TRPH</b>					
EPA 3550A/B015 Modified	mg/Kg				

	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
Report 40473P			
<b>Polychlorinated Biphenyls</b>			
(ug/Kg)			
EPA MM680/HRGC/MS			
	Total PCB's Only - Low Resolution		
2-Mono Congener # 1			
44'-Di # 15			
244'-Tri # 28			
22'55'-Tetra # 52			
33'44'-Tetra # 77			
2344'-5-Penta # 118			
233'44'-Penta # 105			
33'44'5-Penta # 126			
233'44'5-Hexa # 156			
33'44'55'-Hexa # 169			
22'344'55'-Hepta # 180			
22'33'44'55'-Octa # 194			
22'33'44'55'6-Nona # 206			
Deca # 209			
<b>PCB Totals:</b>			
-Mono	0.04		0.04
-Di	0.04		0.04
-Tri	0.04		0.04
-Tetra	0.07		0.07
-Penta	0.09		0.09
-Hexa	0.08		0.08
-Hepta	0.07		0.07
-Octa	0.10		0.10
-Nona	0.1		0.2
-Deca	0.2		0.2

Report 40473Q	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
<b>SVOC's - Page 1 of 2</b>	No data means below detection limit		
EPA 8270A (ug/kg dry weight)	Detection Limits in report do not agree with Detection Limits in data file		
Phenol			
bis(2-Chloroethyl)ether			
2-Chlorophenol			
1,3-Dichlorobenzene			
1,4-Dichlorobenzene			
1,2-Dichlorobenzene			
Benzyl alcohol			
2,2'-oxybis(1-Chloropropane)			
2-Methylphenol			
3/4-Methylphenol			
N-Nitroso-di-n-propylamine			
Hexachloroethane			
Nitrobenzene			
Isophorone			
2-Nitrophenol			
2,4-Dimethylphenol			
bis(2-Chloroethoxy)methane			
Benzoic acid			
2,4-Dichlorophenol			
1,2,4-Trichlorobenzene			
Naphthalene			
4-Chloroaniline			
Hexachlorobutadiene			
4-Chloro-3-methylphenol			
2-Methylnaphthalene			
Hexachlorocyclopentadiene			
2,4,6-Trichlorophenol			
2,4,5-Trichlorophenol			
2-Chloronaphthalene			
2-Nitroaniline			
Dimethylphthalate			
2,6-Dinitrotoluene			
2,4-Dinitrotoluene			

	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
<b>SVOC's - Page 2 of 2</b>			
EPA 8270A (ug/kg dry weight)			
Acenaphthylene			
3-Nitroaniline			
Acenaphthene			
2,4-Dinitrophenol			
4-Nitrophenol			
Dibenzofuran			
Diethylphthalate			46.48 J
4-Chlorophenyl-phenylether			
Fluorene			
4-Nitroaniline			
4,6-Dinitro-2-methylphenol			
N-Nitrosodiphenylamine	17.20 J		
4-Bromophenyl-phenylether			
Hexachlorobenzene			
Pentachlorophenol			
Phenanthrene			
Anthracene			
Di-n-butylphthalate	48.93 BJ		41.96 BJ
Fluoranthene			
Pyrene			
Butylbenzylphthalate			
3,3'-Dichlorobenzidine			
bis(2-Ethylhexyl)phthalate	2584.12 B		333.33 B
Benzo(a)anthracene			
Chrysene			
Di-n-octylphthalate			
Benzo(b)fluoranthene			
Benzo(k)fluoranthene			
Benzo(e)pyrene			
Benzo(a)pyrene			
Perylene			
Indeno(1,2,3-cd)pyrene			
Dibenz(a,h)anthracene			
Benzo(g,h,i)perylene			

	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
Report 404730r1			
<b>Dioxins and Furans</b> (ng/kg) EPA 8290			
2378-TCDD	0.9		0.8
12378-PeCDD	1.8		1.3
123478-HxCDD	1.6		1.1
123678-HxCDD	1.2		0.8
123789-HxCDD	1.3		1
1234678-HpCDD	1.9		1.5
OCDD	1.9 B		8.0 B
2378-TCDF	0.8		0.7
12378-PeCDF	1.2		0.9
23478-PeCDF	1.2		0.9
123478-HxCDF	1.4		0.4 B
123678-HxCDF	1		0.7
234678-HpCDF	0.48 B		0.38 B
123789-HxCDF	1.6		1
1234678-HpCDF	1.6		1.6 B
1234789-HpCDF	2		1.3
OCDF	2.2		0.81 B
Totals: Dioxins			
-TCDD	0.9		0.8
-PeCDD	1.8		1.3
-HxCDD	1.3		1
-HpCDD	1.9		1.5
Totals: Furans			
-TCDF	0.8		0.7
-PeCDF	1.2		0.9
-HxCDF	0.48 B		0.78
-HpCDF	1.8		1.6 B

Report 40473N	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
<b>Metals</b>			
(mg/Kg)			
EPA 6010A & EPA 7471		WV-03-02-01B Duplicate	
Ag	2.62	2.70	2.46
As	5.34	5.24	4.25
Be	1.92	2.11	1.90
Cd	0.906	0.985	0.953
Cr	932	981	1090
Cu	1000	1050	1180
Ni	238	252	290
Pb	108	114	92
Sb	0.808	0.803	1.340
Se	1.72	1.34	1.60
Tl	4.97	5.72	6.17
Zn	1180	1250	1290
Hg (total)	0.092		0.085

Quenched Glass TCLP

Report 40473K	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
<b>Polychlorinated Biphenyls</b> (ng/L Extract)	TCLP		
EPA MM680/HRGC/MS			
2-Mono Congener # 1	0.1	0.02	0.09
44'-Di # 15	0.1	0.02	0.09
244'-Tri # 28	0.14 PR	0.19 PR	0.11 PR
22'55'-Tetra # 52	0.2	0.15	0.17
33'44'-Tetra # 77	0.1	0.03	0.2
2344'5-Penta # 118	0.2	0.35 PR	0.2
233'44'-Penta # 105	0.2	0.10	0.2
33'44'5-Penta # 126	0.2	0.04	0.2
233'44'5-Hexa # 156	0.2	0.06	0.2
33'44'55'-Hexa # 169	0.2	0.07	0.3
22'344'55'-Hepta # 180	0.27 B	0.6 B	0.35 B
22'33'44'55'-Octa # 194	0.3	0.10	0.16
22'33'44'55'6-Nona # 206	0.3	0.1	0.4
Deca # 209	0.2	0.1	0.3
<b>PCB Totals:</b>			
-Mono	0.1	0.02	0.09
-Di	0.1	0.16	0.09
-Tri	0.22	0.80 PR	0.11 PR
-Tetra	0.1	1.4	0.11 PR
-Penta	0.36 B	2.0 PR B	0.10 B
-Hexa	0.93 B	5.0	0.99 B
-Hepta	0.17 B	1.9 B	0.68 B
-Octa	0.3	0.11	0.16
-Nona	0.3	0.1	0.4
			variation of detection limit from sample to sample
			blank
			0.19
			0.51
			0.26
			0.87
			1.50
			0.87

	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
Report 40473J			
SVOC's - Page 1 of 2	TCLP		
EPA 8270A (ug/L Extract)			
Phenol	1.53	1.59	1.59
bis(2-Chloroethyl)ether	2.32	2.41	2.42
2-Chlorophenol	1.71	1.78	1.79
1,3-Dichlorobenzene	1.56	1.62	1.62
1,4-Dichlorobenzene	1.50	1.56	1.56
1,2-Dichlorobenzene	1.63	1.70	1.70
Benzyl alcohol	2.13	2.22	2.23
2,2'-oxybis(1-Chloropropane)	2.93	3.04	3.05
2-Methylphenol	2.18	2.27	2.28
3/4-Methylphenol	2.03	2.11	2.12
N-Nitroso-di-n-propylamine	3.24	3.37	3.38
Hexachloroethane	2.89	3.01	3.02
Nitrobenzene	2.09	2.19	2.11
Isophorone	1.17	1.22	1.18
2-Nitrophenol	3.34	3.50	3.38
2,4-Dimethylphenol	2.37	2.48	2.40
bis(2-Chloroethoxy)methane	1.99	2.08	2.01
Benzoic acid	3.27	3.43	3.31
2,4-Dichlorophenol	2.31	2.42	2.34
1,2,4-Trichlorobenzene	1.85	1.93	1.87
Naphthalene	0.70	0.73	0.71
4-Chloroaniline	1.58	1.66	1.60
Hexachlorobutadiene	3.18	3.34	3.22
4-Chloro-3-methylphenol	2.72	2.85	2.75
2-Methylnaphthalene	1.10	1.15	1.11
Hexachlorocyclopentadiene	3.00	3.17	2.88
2,4,6-Trichlorophenol	3.17	3.35	3.04
2,4,5-Trichlorophenol	3.25	3.44	3.12
2-Chloronaphthalene	1.10	1.16	1.06
2-Nitroaniline	4.87	5.16	4.68
Dimethylphthalate	1.05	1.11	1.01
2,6-Dinitrotoluene	4.60	4.87	4.42
2,4-Dinitrotoluene	3.69	3.91	3.54

SVOC's - Page 2 of 2	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
EPA 8270A (ug/L Extract)	TCLP		
Acenaphthylene	0.69	0.73	0.66
3-Nitroaniline	4.17	4.41	4.00
Acenaphthene	1.19	1.26	1.14
2,4-Dinitrophenol	8.99	9.51	8.63
4-Nitrophenol	5.71	6.04	5.48
Dibenzofuran	0.84	0.89	0.81
Diethylphthalate	0.90	0.95	0.86
4-Chlorophenyl-phenylether	2.19	2.32	2.10
Fluorene	1.11	1.18	1.07
4-Nitroaniline	3.57	3.78	3.42
4,6-Dinitro-2-methylphenol	4.88	4.98	4.95
N-Nitrosodiphenylamine	1.70	1.74	1.73
4-Bromophenyl-phenylether	3.48	3.55	3.53
Hexachlorobenzene	2.54	2.59	2.57
Pentachlorophenol	3.50	3.57	3.55
Phenanthrene	0.71	0.73	0.72
Anthracene	0.72	0.73	0.73
Di-n-butylphthalate	<b>2.18 BJ</b>	<b>1.52 BJ</b>	<b>2 BJ</b>
Fluoranthene	0.57	0.58	0.58
Pyrene	0.46	0.47	0.46
Butylbenzylphthalate	0.69	0.71	0.69
3,3'-Dichlorobenzidine	1.48	1.51	1.47
bis(2-Ethylhexyl)phthalate	<b>0.73 J</b>	0.51	0.49
Benzo(a)anthracene	0.53	0.55	0.53
Chrysene	0.51	0.52	0.51
Di-n-octylphthalate	0.29	0.29	0.30
Benzo(b)fluoranthene	0.46	0.46	0.48
Benzo(k)fluoranthene	0.45	0.45	0.46
Benzo(a)pyrene	0.48	0.48	0.50
Indeno(1,2,3-cd)pyrene	0.44	0.45	0.46
Dibenz(a,h)anthracene	0.61	0.61	0.63
Benzo(g,h,i)perylene	0.47	0.47	0.49
Benzo(e)pyrene	0.47	0.47	0.48
Perylene	0.54	0.55	0.56

Report 40473L	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass
Dioxins and Furans (pg/L Extract) EPA 8290	TCLP		
2378-TCDD	2.4	1.7	2.6
12378-PeCDD	4.1	3.0	4.2
123478-HxCDD	4.4	3.3	3.7
123678-HxCDD	4.0	3.0	3.4
123789-HxCDD	3.9	2.9	3.3
1234678-HpCDD	5.3	4.0	3.6
OCDD	8.2	9.7 B	7.3 B
2378-TCDF	1.9	1.6	2.1
12378-PeCDF	2.5	1.8	2.6
23478-PeCDF	2.5	1.8	2.5
123478-HxCDF	2.9	2.2	2.5
123678-HxCDF	2.3	1.8	2.0
234678-HxCDF	3.6	5.2	3.5 B
123789-HxCDF	3.2	2.4	2.8
1234678-HpCDF	2.8	2.0	2.0
1234789-HpCDF	4.3	3.1	3.1
OCDF	7.0	7.7	2.8
Totals: Dioxins			
-TCDD	2.4	1.7	2.6
-PeCDD	4.1	3.0	4.2
-HxCDD	4.6	3.2 B	3.5
-HpCDD	5.3	4.0	3.6
Totals: Furans			
-TCDF	1.9	1.6	2.1
-PeCDF	2.5	1.8	2.6
-HxCDF	3.6	5.2	3.5 B
-HpCDF	3.4	2.4	2.5

	WV-03-02-01B Quenched Glass	WV-03-02-02B Quenched Glass	WV-03-02-09B Quenched Glass	
Report 404731 and 40473W	Reporting detection Limits are 1 to 10 x the detection limit			
TCLP Metals	Instrument Detection Limits are 0.2 to 8 ppb			
(mg/L Extract)	No data flags			
EPA 6010A & EPA 7471	Blanks were < 2ppb			
Ag	0.0010	0.0010	0.0010	Reg Level 5.00
As	0.0050	0.0050	0.0050	5.00
Be				
Cd	0.0010	0.0010	0.0040	1.00
Cr	0.0600	0.0580	0.0380	5.00
Cu	0.134	0.137	0.564	
Ni	0.030	0.024	0.053	
Pb	0.0140	0.0130	0.0060	5.00
Sb				
Se	0.0030	0.0030	0.0030	1.00
Tl				
Zn	0.166	0.162	0.316	
Hg (total)	0.0004	0.0004	0.0004	0.2
Fe	3.52	3.55	4.50	

Added Materials

	WP-D1-05-01B Hydrated Lime ethod Blank < 3 ppb	WP-M1-09-01B Lime	WP-M1-10-01B Soda Ash
(mg/kg WET weight) EPA 6010A & EPA 7471			
Ag	0.20	0.19	0.19
As	1.68	0.97	0.95
Be	0.20	0.19	0.19
Cd	0.20	0.19	0.19
Cr	1.99	14.50	0.38
Cu	1.68	1.08	0.50
Ni	1.78	1.68	0.57
Pb	0.39	0.39	0.38
Sb	0.79	0.78	0.76
Se	0.59	0.58	0.57
Tl	0.98	0.97	0.95
Zn	2.36	14.70	2.28
Hg (total)	0.10	0.09	0.09
Report			
VOC'S			
ug/L			
8240A Rev.1			
Chloromethane			
Vinyl Chloride			
Bromomethane			
Chloroethane			
Trichlorofluoromethane			
1,1-Dichloroethene			
Carbon disulfide			
Acetone			
Methylene chloride			
trans-1,2-Dichloroethene			
1,1-Dichloroethane			
cis-1,2-Dichloroethene			
Chloroform			
1,2-Dichloroethane			
Vinyl acetate			
2-Butanone			
1,1,1-Trichloroethane			
Carbon tetrachloride			
Benzene			

	WP-D3-07-0nB* Filtrate Water	WP-R1-2A-0nB* Rinse Water	WV-03-4B-0nB* Initial Scrubber Water	WV-03-4A-0nB* Final Scrubber Water	WP-D3-07-0nB* Duplicate	WV-03-4B-0nB* Duplicate
<b>Gross Physico-Chemical Properties</b>						
<b>Particle size</b> (% Dry Weight)						
ASTM D422 (Mod)						
Medium gravel > 4.75 mm						
Fine gravel 2-4.75						
V. coarse sand 0.85-2						
Coarse sand 0.425-0.85						
Medium sand 0.24-0.425						
Fine sand 0.106-0.24						
V. fine sand 0.075-0.106						
Clay < 0.0039						
Silt 0.0039-0.0625						
<b>pH</b>						
EPA 9045A pH Units	12.25		8.29		12.26	8.26
<b>Solids (total)</b>						
EPA 160.3 % dry wt.						
<b>Sulfides (total)</b>						
EPA 9030M mg/L	0.05				2.0	0.05
<b>Organic carbon (total)</b>						
ASTM D4129-82M mg/L	51.00		1.20		51.00	1.20
<b>TRPH</b>						
EPA 3550A/8015 Modified ug/L	1870		50		1840	

	WP-D3-07-0nB*	WP-R1-2A-0nB*	WV-03-4B-0nB*	WV-03-4A-0nB*	WP-D3-07-0nB*
	Filtrate Water	Rinse Water B = analyte found in blank PB = Possible co-eluting peak	Initial Scrubber Water	Final Scrubber Water	Duplicate
Report 40473B and 40473Br1 and 40473T Polychlorinated Biphenyls (ng/L)					
EPA MM680/HRGC/MS	40473Br1	40473B	40473Br1	40473T	
2-Mono	0.67 B	0.03	0.01 B	Total PCB's Only	
44'-Di	0.15	0.03	0.01		
244'-Tri	0.09 PR B	0.04 B	0.05 PR B		
22'55'-Tetra	0.09	0.09 B	0.07		
33'44'-Tetra	0.02	0.07	0.12		
2344'5'-Penta	0.09 B	0.05 B	0.11 B		
23344'-Penta	0.02	0.08	0.13 B		
33'44'5'-Penta	0.02	0.08	0.18		
233'44'5'-Hexa	0.02	0.08	0.16 B		
33'44'55'-Hexa	0.03	0.09	0.24		
22'344'55'-Hepta	0.14 B	0.21 B	0.27 B		
22'33'44'55'-Octa	0.05 B	0.10	0.29 B		
22'33'44'55'6'-Nona	0.06	0.20	0.40		
Deca	0.04	0.10	0.26		
<b>PCB Totals:</b>					
-Mono	0.79	0.02	0.01	2	
-Di	0.49	0.06	0.06	1	
-Tri	0.52	0.38	0.24	2	
-Tetra	0.13	0.27	0.41	3	
-Penta	0.56	0.19	0.41	4	
-Hexa	0.68	0.88	0.73	3	
-Hepta	0.22	0.43	0.36	3	
-Octa	0.05	0.02	0.29	4	
-Nona	0.06	0.20	0.40	5	
-Deca				8	

Sidestreams

	WP-D3-07-0nB* Filtrate Water	WP-R1-2A-0nB* Rinse Water	WV-03-4B-0nB* Initial Scrubber Water	WV-03-4A-0nB* Final Scrubber Water	WP-D3-07-0nB* Duplicate
Report 40473A and 40473U					
SVOC's - Page 1 of 2					
EPA 8270A (ug/L)					
Phenol	1.63	1.29	1.31	5.72	
bis(2-Chloroethoxy)ether	2.02	1.53	1.56	9.18	
2-Chlorophenol	1.75	1.50	1.52	5.57	
1,3-Dichlorobenzene	1.54	1.14	1.16	4.51	
1,4-Dichlorobenzene	1.52	1.17	1.19	4.26	
1,2-Dichlorobenzene	1.67	1.33	1.35	5.02	
Benzyl alcohol	4.57 J	2.41	2.44	9.86	
2,2'-oxybis(1-Chloropropane)	2.32	1.75	1.78	11.78	
2-Methylphenol	1.19 J	1.74	1.76	7.71	
3/4-Methylphenol	7.17 J	1.73	1.75	6.88	
N-Nitroso-di-n-propylamine	2.74	2.11	2.14	10.99	
Hexachloroethane	3.16	2.35	2.38	9.93	
Nitrobenzene	1.72	1.40	1.47	5.75	
Isophorone	2.58 J	0.75	0.79	3.59	
2-Nitrophenol	2.93	2.43	2.56	8.84	
2,4-Dimethylphenol	1.86	1.52	1.60	6.65	
bis(2-Chloroethoxy)methane	1.70	1.37	1.45	6.96	
Benzoic acid	84.84	2.88	3.04	11.49	
2,4-Dichlorophenol	2.21	1.81	1.91	5.41	
1,2,4-Trichlorobenzene	2.02	1.62	1.71	4.36	
Naphthalene	5.34 J	0.57	0.61	2.09	
4-Chloroaniline	1.69	1.34	1.41	4.83	
Hexachlorobutadiene	2.92	2.20	2.32	5.52	
4-Chloro-3-methylphenol	1.96	1.61	1.70	7.01	
2-Methylnaphthalene	0.62 J	0.78	0.83	3.16	
Hexachlorocyclopentadiene	2.95	1.83	1.90	5.06	
2,4,6-Trichlorophenol	3.08	2.15	2.23	6.03	
2,4,5-Trichlorophenol	2.83	2.06	2.14	5.98	
2-Chloronaphthalene	1.13	0.78	0.81	2.53	
2-Nitroaniline	3.12	2.37	2.46	8.94	
Dimethylphthalate	0.85	0.62	0.64	2.13	
2,6-Dinitrotoluene	3.65	2.70	2.80	9.14	
2,4-Dinitrotoluene	2.53	1.95	2.02	6.82	

SVOC's - Page 2 of 2 EPA 8270A (ug/L)	WP-D3-07-0nB*	WP-R1-2A-0nB*	WV-03-4B-0nB*	WV-03-4A-0nB*	WP-D3-07-0nB*
	Filtrate Water	Rinse Water	Initial Scrubber Water	Final Scrubber Water	Duplicate
Acenaphthylene	0.62	0.44	0.46	1.64	
3-Nitroaniline	2.99	2.41	2.50	9.59	
Acenaphthene	<b>0.44 J</b>	0.72	0.75	2.43	
2,4-Dinitrophenol	7.86	5.57	5.78	15.12	
4-Nitrophenol	4.71	4.00	4.16	10.57	
Dibenzofuran	0.74	0.53	0.55	1.76	
Diethylphthalate	0.70	0.54	0.56	1.98	
4-Chlorophenyl-phenylether	1.96	1.46	1.51	3.60	
Fluorene	1.01	0.76	0.79	1.96	
4-Nitroaniline	3.04	2.51	2.61	8.37	
4,6-Dinitro-2-methylphenol	5.28	4.45	4.58	8.45	
N-Nitrosodiphenylamine	1.43	1.32	1.36	2.93	
4-Bromophenyl-phenylether	2.73	2.52	2.59	5.39	
Hexachlorobenzene	2.29	2.15	2.22	4.11	
Pentachlorophenol	3.18	3.07	3.16	6.93	
Phenanthrene	0.73	0.64	<b>0.43 J</b>	1.21	
Anthracene	0.77	0.70	0.72	1.30	
Di-n-butyl phthalate	0.38	<b>1.24 BJ</b>	0.36	1.04	
Fluoranthene	0.59	0.55	<b>0.58 J</b>	1.03	
Pyrene	0.38	0.47	<b>0.6 J</b>	0.94	
Butylbenzylphthalate	0.52	0.66	0.64	2.53	
3,3'-Dichlorobenzidine	0.97	1.85	1.78	3.81	
bis-2-ethylhexylphthalate	<b>0.71 BJ</b>	<b>0.57 BJ</b>	<b>0.82 BJ</b>	<b>1.77 J</b>	
Benzo(a)anthracene	0.37	0.52	0.51	1.26	
Chrysene	0.40	0.58	0.56	1.44	
Di-n-octylphthalate	0.25	0.32	0.31	1.49	
Benzo(b)fluoranthene	<b>0.41 J</b>	0.59	0.57	1.36	
Benzo(k)fluoranthene	0.36	0.64	0.61	1.42	
Benzo(a)pyrene	<b>0.49 J</b>	0.72	0.70	1.63	
Indeno(1,2,3-cd)pyrene	0.30	0.70	0.67	1.54	
Dibenz(a,h)anthracene	0.40	0.94	0.91	1.79	
Benzo(g,h,i)perylene	0.34	0.79	0.76	1.43	
Benzo(e)pyrene	<b>0.43 J</b>	0.67	0.65	1.88	
Perylene	0.41	0.79	0.76	1.63	

	WP-D3-07-0nB* Filtrate Water	WP-R1-2A-0nB* Rinse Water	WV-03-4B-0nB* Initial Scrubber Water	WV-03-4A-0nB* Final Scrubber Water	WP-D3-07-0nB* Duplicate
Report 40473C and 40473S Dioxins and Furans (pg/L) EPA 8290					
2378-TCDD	3.2	1.6	1.7	14	
12378-PeCDD	5.6	2.3	2.9	58.1	
123478-HxCDD	9.3	3.1	4.7	74.4	
123678-HxCDD	7.0	2.3	3.5	7.5	
123789-HxCDD	8.0	2.6	4.0	84.3	
1234678-HpCDD	7.9	2.9	5.5	538	
OCDD	34.0 B	9.2 B	11.0 B	4460	
2378-TCDF	2.1	1.4	1.4	817	
12378-PeCDF	3.6	1.7	1.9	153	
23478-PeCDF	3.6	1.7	1.9	337	
123478-HxCDF	5.9	2.0	2.9	980	
123678-HxCDF	4.3	1.5	2.1	172	
234678-HxCDF	4.5 B	3.8 B	4.4 B	190 B	
123789-HxCDF	6.8	2.3	3.3	60.9 B	
1234678-HpCDF	7.1	2.1	3.6	2030	
1234789-HpCDF	9.0	2.6	4.6	122 B	
OCDF	19.6	3.5	11.2	1520	
Totals: Dioxins					
-TCDD	5.2	1.3	1.7	30.5	
-PeCDD	5.6	2.3	2.9	80.6	
-HxCDD	8.0	7.1	11.2	390	
-HpCDD	7.9	2.9	5.5	1030	
Totals: Furans					
-TCDF	2.1	1.8	1.4	3320	
-PeCDF	3.6	1.7	1.9	3280	
-HxCDF	4.5	3.8	4.4	2090	
-HpCDF	7.9	2.3	4.0	2160 E	

Sidestreams

Report 40473D and 40473R Metals (mg/L) EPA 6010A & EPA 7471	WP-D3-07-0nB*	WP-R1-2A-0nB*	WV-03-4B-0nB*	WV-03-4A-0nB*	WP-D3-07-0nB*
	Filtrate Water	Rinse Water	Initial Scrubber Water	Final Scrubber Water	Duplicate
	Method Blanks are < 3ppb except Tl which is 7ppb				
Ag	0.001	0.001	0.002	0.377	0.001
As	0.013	0.005	0.005	0.791	0.012
Be	0.001	0.001	0.001	0.002	0.001
Cd	0.001	0.001	0.006	1.30	0.001
Cr	0.002	0.002	0.080	22.1	0.002
Cu	0.195	0.054	0.015	3.13	0.189
Ni	0.130	0.003	0.004	0.283	0.127
Pb	0.015	0.003	0.205	14.0	0.015
Sb	0.004	0.004	0.004	0.174	0.004
Se	0.079	0.003	0.003	0.095	0.048
Tl	0.006	0.005	0.005	0.067	0.006
Zn	0.174	0.024	0.608	51.1	0.172
Hg (total)	0.005	0.001	0.001	0.0011	
Report					
VOC'S					
ug/L					
8240A Rev.1					
Chloromethane					
Vinyl Chloride					
Bromomethane					
Chloroethane					
Trichlorofluoromethane					
1,1-Dichloroethene					
Carbon disulfide					
Acetone					
Methylene chloride					
trans-1,2-Dichloroethene					
1,1-Dichloroethane					
cis-1,2-Dichloroethene					
Chloroform					
1,2-Dichloroethane					
Vinyl acetate					
2-Butanone					

## **Appendix B - Corning Engineering Services Laboratory Sediment Sample Analyses**

The following are chemical analyses of sediment samples generated during Phase II Demonstration Test 3.

<b>Sample Log</b>	<b>B-2</b>
<b>Sediment Overall Composition Analyses</b>	<b>B-3</b>
<b>Sediment Trace Metal Semiquantitative Analyses</b>	<b>B-4</b>

Corning Incorporated  
CELS—Laboratory Services  
Technology Sales & Licensing  
HP ME 03 078 G6  
Corning, New York 14831  
800-235-2357  
607-974-6601  
fax 607-974-6522

Page 1 of 4

July 24, 1996

Ms. Nancy Ulerich  
Westinghouse STC  
1310 Beulah Road  
Pittsburgh, PA 15235

CELS Client No.: 17220-003  
Date Received : 17-JUL-96  
Date Reported : 24-JUL-96  
Reviewed &  
Approved by : Connie Fieno

**CORNING**

Connie Fieno  
Analysis  
Coordinator

Copy to: CELS File

---

SAMPLE IDENTIFICATION:

Sample 1: Sediments, Grab A; Received 7-17-96  
Sample 2: Sediments, Grab B; Received 7-17-96

ANALYSIS REPORTED:

Exhibit

- A Quantitative Chemical Analysis
- B Semi-Quantitative Spectrographic Analysis

COMMENTS:

Client Purchase Order No. 34-20221-PR

Direct questions regarding this report to Connie Fieno, CELS office.

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LABORATORY ANALYSIS REPORT

CELS Client No.: 17220-003

Exhibit A: Quantitative Chemical Analysis

## Sample Description:

Sample 1: Sediments, Grab A; Received 7-17-96

Sample 2: Sediments, Grab B; Received 7-17-96

Lab I.D. No.: 16529-96

<u>Determination</u>	<u>Results (Wt.%)</u>		<u>Test Method</u>
	<u>Sample 1</u>	<u>Sample 2</u>	
K <sub>2</sub> O	2.05	2.05	FES
Na <sub>2</sub> O	2.90	3.34	FES
Al <sub>2</sub> O <sub>3</sub>	9.56	10.3	PLS
CaO	5.71	1.89	PLS
Fe <sub>2</sub> O <sub>3</sub>	5.43	6.08	PLS
MgO	1.89	2.09	PLS
SiO <sub>2</sub>	48.8	49.3	PLS
C	8.2	9.5	LECO
SO <sub>3</sub>	6.0	7.6	LECO
LOD	61.0	62.3	LOD
LOI	66.5	68.1	LOI
Cl	1.66	1.51	TITR

LEGEND:

FES: Flame Emission Spectroscopy  
 PLS: Plasma/Emission Spectroscopy  
 LECO: LECO Instrumentation  
 LOD: Loss on Drying at 110°  
 LOI: Loss on Ignition at 650°  
 TITR: Titrimetry

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LABORATORY ANALYSIS REPORT

CELS Client No.: 17220-003

## Exhibit B: Semi-Quantitative Spectrographic Analysis

## Sample Description:

Sample 1: Sediments, Grab A; Received 7-17-96

Sample 2: Sediments, Grab B; Received 7-17-96

Lab I.D. No.: 16529-96

<u>Range %</u>	<u>(ELEMENT)</u>	
	<u>Sample 1</u>	<u>Sample 2</u>
> 30	Si	Si
10 - 30	-	-
3.0 - 10	Al, Fe	Al, Fe
1.0 - 3.0	Ca-, Na+	Ca-, Mg-, Na+
0.3 - 1.0	K, Mg+, Ti, Zn-	K, Ti, Zn-
0.1 - 0.3	Cu	Cu
0.03 - 0.1	Cr-, Mn, Ni-, Pb	Cr, Mn, Ni-, Pb
0.01 - 0.03	B-, Ba, Sn-, V, Zr-	B-, Ba, Sn-, V, Zr-
0.003 - 0.01	Ga, Sr-	Sr-
0.001 - 0.003	Ag-, Co, Mo-	Ag-, Co, Ga, Mo-

Comment: Typical detection limits (Wt%) for the ELEMENTS EXAMINED are listed below. They are ONLY general guidelines. Detection limits are composition affected. For oxide conversion factors and a list of other elements that can be detected; see the attached chart.

0.3% - K, P  
 0.1% - As, Cd, Li  
 0.03% - Nb, Zn  
 0.01% - Ba, Na, Sb, Zr  
 0.003% - Al, Co, In, Ni, Si, Ti  
 0.001% - Ag, B, Be, Bi, Ca, Cu, Cr, Fe, Ga, Ge, Mg, Mn, Mo, Pb, Sn, Sr, V

NOTE: (+) after element = upper range and (-) after element = lower range.

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LABORATORY ANALYSIS REPORT

CELS Client No.: 17220-003

## Exhibit B: Semi-Quantitative Spectrographic Analysis (Continued)

FACTORS FOR CONVERSION OF ELEMENTS TO OXIDE**							
Ag2O	1.07	FeO	1.29	Na2O	1.35	Ta2O5	1.22
Al2O3	1.89	Fe2O3	1.43	Nb2O3	1.43	Tb4O7	1.18
As2O3	1.32	Ga2O3	1.34	Nd2O3	1.17	TeO2	1.25
As2O5	1.53	Gd2O3	1.15	NiO	1.27	TiO2	1.67
B2O3	3.22	GeO2	1.44	P2O5	2.29	Tl2O	1.04
BaO	1.12			PbO	1.08	Tl2O3	1.12
BeO	2.78	Ho2O3	1.15	PbO2	1.15	Tm2O3	1.14
Bi2O3	1.11	HfO2	1.18	Pr2O3	1.17		
		In2O3	1.21			VO	1.31
CaO	1.40			RuO2	1.32	VO2	1.63
CdO	1.14	K2O	1.20	RuO4	1.63	V2O5	1.79
CeO2	1.23	La2O3	1.17				
CoO	1.27	Li2O	2.15	Sb2O3	1.20	WO2	1.17
Cr2O3	1.46	Lu2O3	1.14	Sb2O5	1.33	WO3	1.26
CuO	1.25			Sc2O3	1.53		
Cu2O	1.13	MgO	1.66	SiO2	2.14	Y2O3	1.27
		MnO	1.29	Sm2O3	1.16	Yb2O3	1.14
Dy2O3	1.15	MnO2	1.58	SnO	1.13	ZnO	1.24
Er2O3	1.14	MoO3	1.50	SnO2	1.27	ZrO2	1.35
Eu2O3	1.16			SrO	1.18		

\*\* Semi-Quantitative Spectrographic Analysis results are quoted as weight percent of the element (not as the oxide). To convert weight percent element to weight percent oxide, just multiply the percent element by the appropriate factor listed in the above table.

Below is a list of the ELEMENTS that are determined by spectrographic analysis. Analyses are divided into three categories: GENERAL QUANT, NOBEL METALS, AND RARE EARTHS ANALYSES. Nobel Metals and /or Rare Earths may be requested as a group or only by the elements of interest.

General Quant Analysis - Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Ge, In, K, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Sb, Si, Sn, Sr, Ti, V, Zn, Zr, (If requested) - Ta, Te, Tl, W

NOBEL METALS ANALYSIS		RARE EARTHS ANALYSIS			
ELEMENTS	DETECTION %	ELEMENT	DETECTION %	ELEMENT	DETECTION %
Au	0.003	Ce	0.1	Nd	0.3
Ga	0.001	Dy	0.1	Pr	0.1
Hf	0.03	Er	0.03	Sc	0.01
In	0.001	Eu	0.01	Sm	0.1
Ir	0.01	Gd	0.03	Tb	0.03
Pd	0.001	Ho	0.03	Tm	0.01
Pt	0.01	La	0.1	Y	0.003
Re	0.03	Lu	0.01	Yb	0.003
Rh	0.003				
Ru	0.03				

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## **Appendix C - Spectrochemical Laboratories Feed and Glass Sample Analyses**

The following are chemical analyses of plasma feed and product glass samples generated during Phase II Demonstration Test 3.

<b>Feed and Glass Overall Composition Analyses</b>	<b>C-2</b>
<b>Feed and Glass Semiquantitative Trace Metal Analyses</b>	<b>C-3</b>

# Spectrochemical Laboratories, Inc.

Telephone: 412-371-2345  
 FAX: 412-371-0463

8350 FRANKTOWN AVENUE  
 PITTSBURGH, PA. 15221



Westinghouse Electric Corporation  
 Science & Technology Center  
 1310 Beulah Road  
 Pittsburgh, PA 15235

January 14, 1997  
 Sample Recd. 12-30-96  
 Your PO# 450002417  
 Our Lab# E7256  
 Page 1 of 2

Attn: Nancy Ulerich

## ANALYSIS REPORT RESULTS IN WEIGHT % ON AS RECEIVED BASIS

OUR LAB #E7256 YOUR ID	-1	-2	-3	-4
	Plasma Feed WP-D4- 08-11W	Plasma Feed WP-M1- 11-10W	Product Glass A-2 Feed 11:15 AM	Product Glass (Batch B1) WU-3-2-088
H <sub>2</sub> O	48.72	44.67	.13	3.28

### ON DRY BASIS IN WEIGHT %

LOI(Loss On Ignition)	20.55	20.43		
Ignition Gain			.20	.42
C	8.30	8.70	.015	.025
S			.009	.038
Cl <sup>-</sup>	.73	.88	<.01	<.01

### ON CALCINED BASIS IN WEIGHT %

SO <sub>3</sub>	2.86	3.39		
SiO <sub>2</sub>	47.95	46.98	46.45	49.34
CaO	11.00	14.87	11.57	13.47
Fe <sub>2</sub> O <sub>3</sub>	6.36	7.51	6.76	7.33
MgO	2.30	2.21	2.23	2.38
TiO <sub>2</sub>	.67	.59	.68	.74
Al <sub>2</sub> O <sub>3</sub>	11.30	11.11	16.86	15.30
ZnO	.22	.26	.16	.17
CuO	.16	.19	.14	.19

< Less than

Report continued on Page 2

As a mutual protection to clients, the public and ourselves, all reports are submitted as the confidential property of clients, and authorization for publication of statements, conclusions or extracts from or regarding our reports is reserved pending our written approval.

# Spectrochemical Laboratories, Inc.

Telephone: 412-371-2345  
FAX: 412-371-0463

8350 FRANKSTOWN AVENUE  
PITTSBURGH, PA. 15221



January 14, 1997  
Sample Recd. 12-30-96  
Your PO# 4500002417  
Our Lab# E7256  
Page 2 of 2

Westinghouse Electric Corporation

Attn: Nancy Ulerich

## ANALYSIS REPORT ON CALCINED BASIS IN WEIGHT %

(Cont.)

OUR LAB #E7256 YOUR ID	-1	-2	-3	-4
	Plasma Feed WP-D4 08-11W	Plasma Feed WP-M1- 11-10W	Product Glass A-2 Feed 11:15 AM	Product Glass (Batch B1) WU-3-2-088
Cr <sub>2</sub> O <sub>3</sub>	.064	.071	.16	.26
Na <sub>2</sub> O	14.50	10.28	12.65	8.09
K <sub>2</sub> O	2.11	1.90	1.75	1.99
P <sub>2</sub> O <sub>5</sub>			.51	.65
ZrO <sub>2</sub>			.027	.031

## QUALITATIVE SPECTROGRAPHIC ANALYSIS WITHOUT STANDARDS RESULTS IN WEIGHT %

SrO	.03	.02	.005	.01
MnO	.005	.005	.005	.01
NiO	.005	.005	.005	.005
V <sub>2</sub> O <sub>5</sub>	.005	.005	.005	.005
PbO	.005	.005	.005	.005
BaO	.003	.003	.003	.003
B <sub>2</sub> O <sub>3</sub>	.003	.003	.003	.003
SnO <sub>2</sub>	.001	.001	.001	.001
Ag <sub>2</sub> O	.001	.001	<.001	<.001

< Less than

Not Detected: Cd, As, Te, P, Sb, W, Ge, Bi, Be, Mo, Li, Co

SPECTROCHEMICAL LABORATORIES, Inc.

T. L. Fulton

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## **Appendix D - Antech Scrubber Water Sample Analyses**

The following are chemical TSS, chloride, and sulfur analyses of scrubber water samples generated during Phase II Demonstration Test 3.

<b>Sample Log</b>	D-3
<b>Scrubber Water TSS, Chlorine, and Sulfur</b>	D-4



## Antech Ltd.

One Triangle Drive • Export, Pennsylvania 15632 • Phone: (412) 733-1161 • Fax: (412) 327-7793

January 13, 1997

Ms. Nancy Ulerich  
Westinghouse Electric Corporation STC  
1310 Beulah Road  
Pittsburgh, PA 15235-5098

Water Characterization; Purchase Order No. 4500002341  
Antech Ltd. Project No. 96-6140

Dear Ms. Ulerich:

Enclosed are analytical results for samples submitted by Westinghouse Electric Corporation STC. Samples were received and logged in for analysis on December 27, 1996.

Appropriate U.S. Environmental Protection Agency methods were used and are indicated accordingly on the data table. Appropriate quality assurance/quality control analyses were performed in accordance with Antech Ltd.'s Statement of Qualifications. If you have any questions, please call me.

Sincerely,

  
Paula Y. Crawford  
Project Coordinator  
PYC:aeb

Enclosures

ANTECH LTD.  
CASE NARRATIVE

I. PROJECT LOGIN INFORMATION:

A: PROJECT NUMBERS:

ANTECH LTD.: 96-6140

CLIENT: Purchase Order Number: 4500002341

B: SAMPLE IDENTIFICATIONS:

Antech ID	Client ID	Antech ID	Client ID
9612-2579	WV-3-4A-01B	9612-2580	WV-3-4A-03B
9612-2581	WV-3-4A-08B	9612-2582	WV-3-4A-09B
9612-2583	WV-3-4A-10B	9612-2584	WV-3-4A-11B

C: SHIPPING/RECEIVING COMMENTS:

None

II. PREPARATION/ANALYSIS COMMENTS:

A: GENERAL CHEMISTRY:

None

B: METALS:

None

III. GENERAL COMMENTS:

Trailing zeroes and decimal places appearing on the data should not be interpreted as precision of the analytical procedure, but rather as a result of reporting format.

**Table 1**  
**General Data Table**  
**Westinghouse Electric Corporation STC**  
**Antech Ltd. Project No. 96-6140**  
**Water Characterization**  
**Purchase Order No. 4500002341**

Page 1 of 2

Parameter	Analytical Method	Units	Sample Identification			
			9612-2579 WV-3-4A-01B (12/27/96)	9612-2580 WV-3-4A-03B (12/27/96)	9612-2581 WV-3-4A-08B (12/27/96)	9612-2582 WV-3-4A-09B (12/27/96)
Total Suspended Solids @ 105°C	160.2(1)	mg/l	259	269	38	103
Percent Chlorine	D 808(2)	%	0.11	0.15	0.19	0.20
Total Sulfur	B129(2)	%	0.12	0.16	0.19	0.23
Total Metal:						
Sodium (Total)	6010(3)	mg/l	220	340	480	490

See footnotes at end of table.

Table 1  
(Continued)

Parameter	Analytical Method	Units	Sample Identification	
			9612-2583 WV-3-4A-10B (12/27/96)	9612-2584 WV-3-4A-11B (12/27/96)
Total Suspended Solids @ 105°C	160.2(1)	mg/l	38	152
Percent Chlorine	D 808(2)	%	0.35	0.13
Total Sulfur	B129(2)	%	0.25	0.26
Total Metal:				
Sodium (Total)	6010(3)	mg/l	510	470
				<1
				NP(4)
				NP
				<1.0

(1) U.S. Environmental Protection Agency, 1983, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio.

(2) American Society for Testing and Materials, Annual Book of ASTM Standards, Philadelphia, PA.

(3) U.S. Environmental Protection Agency, 1987, Test Methods for Evaluating Solid Waste, SW-846, 3rd ed., Office of Solid Waste and Emergency Response, Washington, DC.

(4) NP = Not Provided.

# Appendix E - K Chem Lab Scrubber Water Sample Analyses

Scrubber Water Contaminant Analysis

E-2

# K Chem Lab, Inc

1333 Main Street • Latrobe, PA 15650

(412) 537-6621 • (800) 294-7733

Mr. Tom Martin  
Allegheny Liquid Systems  
RJ Casey Industrial Park  
Columbus & Adams Avenues  
Pittsburgh, PA 15233-1092

Date: January 15, 1997  
Sample ID: 3743A  
Sampled Date: 1/3/97, 10:30  
Page 1 of 1

## Westinghouse Scrubber Water

Parameter	Result	Detection Level	Method
Flash Point	>150° F	5° F	SW-846 1010
Benzene	<1 µg/kg	1 µg/kg	SW-846 8020
Toluene	1.9 µg/kg	1 µg/kg	SW-846 8020
Ethylbenzene	<1 µg/kg	1 µg/kg	SW-846 8020
Total Xylene	1.1 µg/kg	1 µg/kg	SW-846 8020
pH	6.99 a.u.	0.01 a.u.	EPA 150.1
Reactive Cyanide	<0.5 mg/L	0.5 mg/L	SW-846 9010
Reactive Sulfide	<0.5 mg/L	0.5 mg/L	SW-846 9030
TCLP Arsenic	0.338 mg/L	0.005 mg/L	SW-846 7060
TCLP Barium	1.01 mg/L	0.05 mg/L	SW-846 6010
TCLP Cadmium	2.09 mg/L	0.01 mg/L	SW-846 7130
TCLP Chromium	66.7 mg/L	0.01 mg/L	SW-846 7190
TCLP Lead	38.5 mg/L	0.01 mg/L	SW-846 7420
TCLP Mercury	<0.0005 mg/L	0.0005 mg/L	SW-846 7470
TCLP Selenium	0.051 mg/L	0.005 mg/L	SW-846 7741
TCLP Silver	0.51 mg/L	0.01 mg/L	SW-846 7760
Oil & Grease	0.5 mg/L	0.1 mg/L	EPA 413.2
Total Solids	0.5 %	0.1 %	EPA 160.3
Phenols	<0.001 mg/L	0.001 mg/L	SW-846 9065
Total Organic Carbon	6.1 mg/L	1 mg/L	SW-846 9060

Work inspected and certified by:

  
James T. Kratoch

## **Appendix F - Air Quality Services Offgas Sample Analyses**

The following are fixed gas chemical analyses of offgas samples generated during Phase II Demonstration Test 3.

**Offgas Fixed Gas Analyses**

F-2

# AIR QUALITY SERVICES, INC.

4527 Clairton Boulevard  
Pittsburgh, PA 15236  
(412) 881-5630

TABLE I  
ANALYSIS OF GAS CYLINDER FOR SELECTED PARAMETERS  
WESTINGHOUSE ELECTRIC CORPORATION  
SCIENCE & TECHNOLOGY CENTER  
1310 BEULAH ROAD  
PITTSBURGH, PA 15235-5098  
SAMPLE RECEIVED: JANUARY 02, 1997

PARAMETER	CYLINDERS WV-3-3A-01B AND WV-3-3A-02B OFFGASES, MELTER SHAFT
LABORATORY NUMBER	AQS-73579 AND 73580
NITROGEN - PERCENT	76.0
OXYGEN - PERCENT	14.5
ARGON - PERCENT	0.5
CARBON DIOXIDE - PERCENT	7.9
CARBON MONOXIDE - PPM	<1
NITROGEN OXIDES REPORTED AS NITROGEN DIOXIDE - PERCENT	1.1
SULFUR OXIDES REPORTED AS SULFUR DIOXIDE - PERCENT	0.1

THE FIXED GASES WERE ANALYZED BY GAS CHROMATOGRAPHY USING A THERMAL CONDUCTIVITY DETECTOR. THE NITROGEN DIOXIDE AND SULFUR DIOXIDE WERE ANALYZED BY ION CHROMATOGRAPHY USING AN ANION COLUMN.

*John O. Fairman*  
AIR QUALITY SERVICES, INC.

JOB 5465  
REPORTED: JANUARY 09, 1997

# AIR QUALITY SERVICES, INC.

4527 Clairton Boulevard  
Pittsburgh, PA 15236  
(412) 881-5630

TABLE II  
ANALYSIS OF GAS CYLINDER FOR SELECTED PARAMETERS  
WESTINGHOUSE ELECTRIC CORPORATION  
SCIENCE & TECHNOLOGY CENTER  
1310 BEULAH ROAD  
PITTSBURGH, PA 15235-5098  
SAMPLE RECEIVED: JANUARY 02, 1997

PARAMETER	CYLINDERS WV-3-3A-07B AND WV-3-3A-08B OFFGASES, MELTER SHAFT
LABORATORY NUMBER	AQS-73581 AND 73582
NITROGEN - PERCENT	71.2
OXYGEN - PERCENT	10.7
ARGON - PERCENT	0.4
CARBON DIOXIDE - PERCENT	15.2
CARBON MONOXIDE - PPM	<1
NITROGEN OXIDES REPORTED AS NITROGEN DIOXIDE - PERCENT	1.8
SULFUR OXIDES REPORTED AS SULFUR DIOXIDE - PERCENT	0.7

THE FIXED GASES WERE ANALYZED BY GAS CHROMATOGRAPHY USING A THERMAL CONDUCTIVITY DETECTOR. THE NITROGEN DIOXIDE AND SULFUR DIOXIDE WERE ANALYZED BY ION CHROMATOGRAPHY USING AN ANION COLUMN.

*John A. G. Miller*  
AIR QUALITY SERVICES, INC.

JOB 5465  
REPORTED: JANUARY 09, 1997

# AIR QUALITY SERVICES, INC.

4527 Clairton Boulevard  
Pittsburgh, PA 15236  
(412) 881-5630

TABLE III  
ANALYSIS OF GAS CYLINDER FOR SELECTED PARAMETERS  
WESTINGHOUSE ELECTRIC CORPORATION  
SCIENCE & TECHNOLOGY CENTER  
1310 BEULAH ROAD  
PITTSBURGH, PA 15235-5098  
SAMPLE RECEIVED: JANUARY 02, 1997

PARAMETER	CYLINDERS WV-3-3A-12B AND WV-3-3A-13B OFFGASES, MELTER SHAFT
LABORATORY NUMBER	AQS-73583 AND 73584
NITROGEN - PERCENT	77.5
OXYGEN - PERCENT	19.0
ARGON - PERCENT	0.4
CARBON DIOXIDE - PERCENT	1.7
CARBON MONOXIDE - PPM	<1
NITROGEN OXIDES REPORTED AS NITROGEN DIOXIDE - PERCENT	0.9
SULFUR OXIDES REPORTED AS SULFUR DIOXIDE - PERCENT	0.5

THE FIXED GASES WERE ANALYZED BY GAS CHROMATOGRAPHY USING A THERMAL CONDUCTIVITY DETECTOR. THE NITROGEN DIOXIDE AND SULFUR DIOXIDE WERE ANALYZED BY ION CHROMATOGRAPHY USING AN ANION COLUMN.

*L. A. Fisher*  
AIR QUALITY SERVICES, INC.

JOB 5465  
REPORTED: JANUARY 09, 1997

## **Appendix G - Affiliated Environmental Services Offgas Sample Contaminant Analyses**

The following are chemical contaminant analyses of offgas samples generated during Phase II Demonstration Test 3. These pages have been abstracted from the much larger (130 page) AES complete report. In the EAS summary report, numbers generated for dioxins, furans, and semivolatiles are based on assays that were flagged as data in which blank contamination appeared. These totals are not accurate. The individual analysis are provided here so that flagged data can be identified.

<b>Test Procedures</b>	G-3
Offgas Flowrate	G-8
Offgas Fixed Gas Composition	G-9
Dioxins and Furans	G-10
Semivolatile Organic Carbon Compounds	G-14
Hydrochloric Acid and Chlorine	G-18
RCRA Metals	G-19
Polychlorinated Biphenyls	G-21
Pesticides	G-22

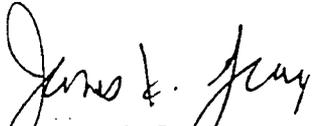


**Brookhaven National Laboratory Associated Universities, Inc.  
Upton, Long Island New York 11973**

**Report**

**Particulate, Dioxins, Furans, Metals, So<sub>2</sub>, No<sub>x</sub>, O<sub>2</sub>, CO<sub>2</sub>, PCB's  
Semivolatile Scan, Pesticide Scan, Chlorobenzene and Chlorophenol**

**Collected between the Quench Spray and Venturi Scrubber  
Westinghouse Plasma Meltor Pilot Plant  
Madison, PA**

  
**James K. Gray**  
**Environmental Supervisor**



## TESTING PROCEDURES

Affiliated Environmental Services, Inc. conducted emissions sampling using method 1-5, 6C, 7E, 23, 26A, 29, 8270, and 8080 between the quench spray and the venturi scrubber. This testing was conducted on December 5, 1996 for performance demonstration. The process burns soil with a plasma torch that is dredged from a river bed. The purpose is to burn off any contaminants that may be present in the soil. The Affiliated test crew consisted of Don Dauch, James Gray, Joe Gillingham and Brad Pean. Due to the limited amount of process running time all sampling was done for an hour each for each of the target compounds. Sampling at the testing location had to be conducted with a one point traverse due to port locations. All QA/QC, methods descriptions, and chain of custody procedures are provided for all of the testing parameters.



#### **METHOD 1**

Sample and velocity traverses for stationary sources.

To aid in the representative measurement of pollutant emissions and/ or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

#### **METHOD 2**

Determination of stack gas velocity and volumetric flow rate.

The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

#### **METHOD 3**

Gas analysis for the determination of dry molecular weight.

This method is applicable for determining carbon dioxide and oxygen concentrations and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process.

#### **METHOD 4**

Determination of moisture content in stack gases.

A gas sample is extracted at a constant rate from the source. It is determined either volumetrically or gravimetrically.



## METHOD 29 TESTING DESCRIPTION

Samples were collected following EPA Method 29. There was a 1 point traverse used due to the location of sampling. Sampling was for a total of a 60 minute test. One 60 minute test repetition was performed. The equipment used for testing consisted of a Fyrite Gas Analyzer and a Graseby/Nutech Train Stack Sampler (EPA type). A RAC type "S" pitot and a heated sampling probe was used with the sampling train. All equipment was calibrated in the laboratory prior to the test. The sampling nozzle and the pitot tubes were measured on the day of the test. All calibrations can be found in the appendix. The gases are passed through a heated pyrex probe and a heated glass four inch filter holder containing Whatman type 934AH fiberglass filter media. The gases leaving the filter were collected in a series of six impingers packed in ice. The first, second, fourth, fifth, and sixth impingers were the modified Greenburg-Smith type and the third one was a standard Greenburg-Smith type. The first impinger is left empty. The second and third impinger contained 100 ml each of  $\text{HNO}_3 / \text{H}_2\text{O}_2$ . The gases then pass through the fourth impinger which is left empty. After leaving the fourth impinger the gases passed through a fifth and sixth impinger containing 100 ml each of acidified  $\text{KMnO}_4$ . They then pass through a seventh impinger with 300 grams of silica gel desiccant to remove any remaining water vapor. The dry gas then passed through the hose portion of the umbilical cord to a Graseby/Nutech "Stack Sampler" module. In the module the gas was moved through the system by a leakless air pump to a Rockwell 175-S dry test meter. The dry test meter exhausted to a calibrated orifice to measure the flow rate of the gases passing through the sampling apparatus. A type "S" pitot tube was attached to the sheath of the heated probe and nozzle. The orifice pressure taps and the pitot tube were connected to a Dwyer dual 10 inch combination inclined-well type manometer. One half of the manometer measured the orifice differential pressure ( $\Delta H$ ) and the other half measured the flue gas velocity head ( $\Delta P$ ). The temperature of the flue gas was measured by a type "K" thermocouple connected to a Fuji temperature controller. The  $\text{CO}_2$  and  $\text{O}_2$  levels were collected into teddlar bags and brought back to the laboratory for orsat analysis. Sampling train recovery was conducted as follows: Container No. 1 contained the filter. Container No. 2 consisted of rinsing and brushing the probe nozzle, probe fitting, probe liner, and front half of the filter holder with 100 ml of acetone. Container No. 3 contained the probe nozzle, probe fitting, probe liner, and front half of the filter holder with 100 ml of 0.1 N  $\text{HNO}_3$ . Container No. 4 consisted of impingers 1 through 3, connecting glassware and back half of filter holder being rinsed with 100 ml of 0.1 N  $\text{HNO}_3$ . Container No. 5A was the fourth impinger being rinsed with 100 ml of 0.1 N  $\text{HNO}_3$ . Container No. 5B consisted of the fifth and sixth impinger with acidified  $\text{KMnO}_4$  being rinsed three times with a total of 100 ml of acidified  $\text{KMnO}_4$ . They are then rinsed with 100 ml of water. Container No.

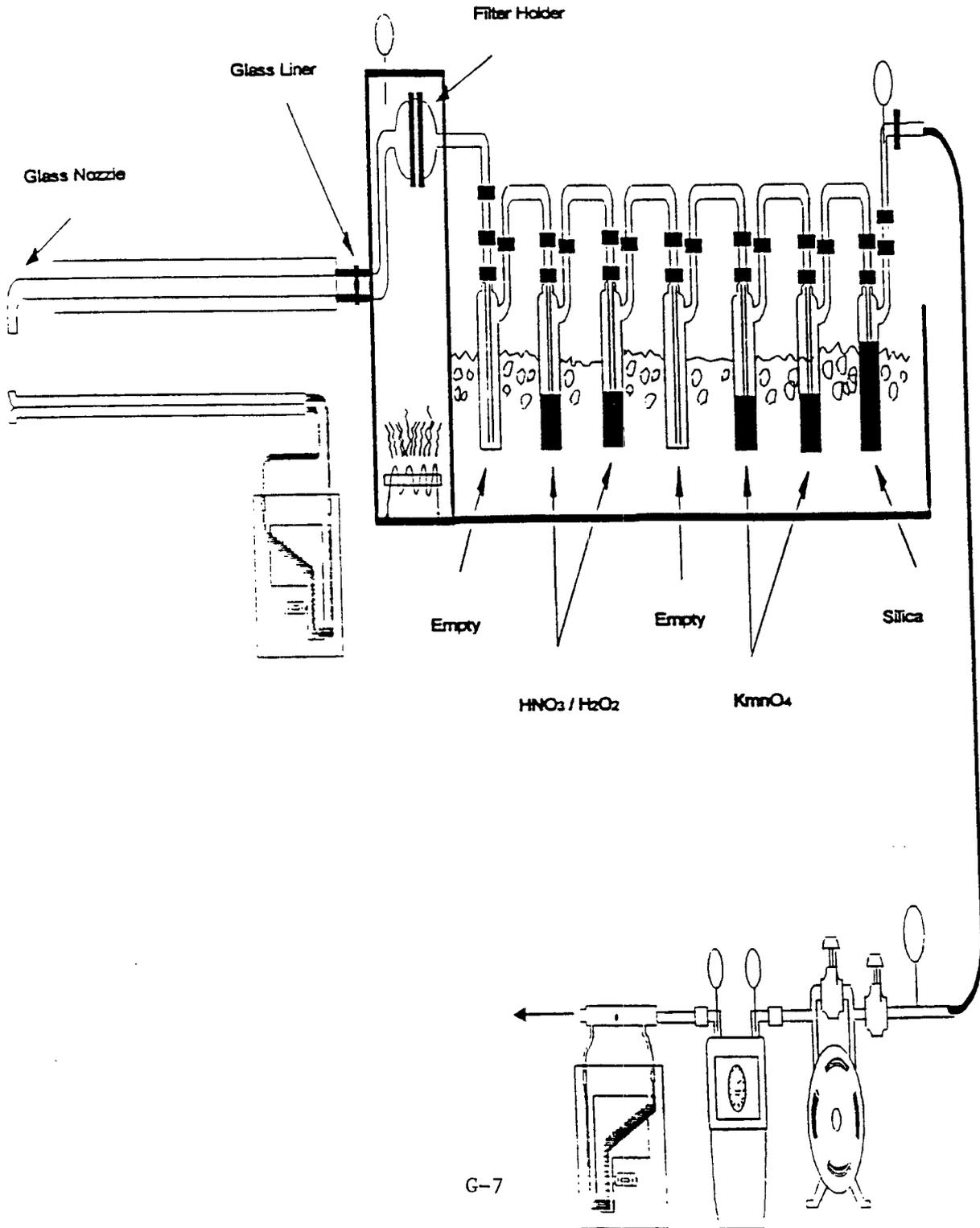


## METHOD 29 TESTING DESCRIPTION CONT.

5C was the fifth and sixth impinger being rinsed with 25ml of 8 N HCL to remove any remaining deposits. The container is initially filled with 200 ml of water. Container No. 6 contains the spent silica gel from impinger number seven. Container No. 7 consisted of 100 ml of a acetone blank used in sample recovery.



# 29 Sampling System





# TEST RESULTS

	Method 23 RUN #1	Method 26 RUN #1	1-5, 29 RUN #1	3A, 6C, 7E RUN #1
VM (std)	49.84	43.30	30.51	
VW (std)	22.00	21.76	5.88	
BWS	0.306	0.334	0.162	0.334
MD	28.95	28.95	28.95	28.95
MS	25.60	25.29	27.18	25.29
VS (ft/sec)	84.76	94.04	90.20	95.16
ACFM	3994.39	4429.13	4248.54	4482.26
DCFM	2443.93	2522.24	3082.02	2493.62
ISOKINETIC %	78.56	66.10	40.83	
<b>PARTICULATE</b>				
LBS/HR			5.07	
GR/DSCF			0.19	

VM (std) = Volume of gas sampled at standard conditions.

VW (std) = Volume of water vapor collected at standard conditions.

BWS = Stack moisture content.

MD = Determination of dry molecular weight of stack gas.

MS = Determination of stack gas molecular weight.

VS = Average gas stack velocity. (ft/sec.)

ACFM = Actual cubic feet per minute of gas velocity.

DCFM = Dry standard cubic feet per minute of gas velocity.

Lbs/Hr = Pounds per Hour.

Gr/Dscf = Grains per dry standard cubic feet.



# TEST RESULTS

	Method 23	Method 26	1-5, 29	3A, 6C, 7E
	RUN #1	RUN #1	RUN #1	RUN #1
<b>CEM MONITORING</b>				
NOX (lbs/hr)				15.30
SO2 (lbs/hr)				1.06
N2 %				80.86
Ar %				2.35
O2 %				17.61
CO2 %				1.53

# Affiliated Environmental Services

TLI Project: **39931C** Method 23 PCDD/PCDF Analysis (a)  
 Client Sample: **XAD Train XAD,IMP** Analysis File: **W146011**

*Back Half, < Sum particles*

<b>Client Project: Brookhaven-Pennsylvania</b>			
Sample Matrix: <b>M23</b>	Date Received: <b>12/10/96</b>	Spike File: <b>SPX23704</b>	
TLI ID: <b>149-70-1BDE</b>	Date Extracted: <b>12/12/96</b>	ICal: <b>WF55116</b>	
	Date Analyzed: <b>12/21/96</b>	ConCal: <b>W145901</b>	
Sample Size: <b>1.000</b>	Dilution Factor: <b>n/a</b>	% Moisture: <b>n/a</b>	
Dry Weight: <b>n/a</b>	Blank File: <b>W145817</b>	% Lipid: <b>n/a</b>	
GC Column: <b>DB-5</b>	Analyst: <b>MM</b>	% Solids: <b>n/a</b>	

Analytes	Amt. (ng)	DL	EMPC	Ratio	RT	Flags
2,3,7,8-TCDD	EMPC		0.002			—
1,2,3,7,8-PeCDD	ND	0.004				—
1,2,3,4,7,8-HxCDD	EMPC		0.004			—
1,2,3,6,7,8-HxCDD	EMPC		0.004			—
1,2,3,7,8,9-HxCDD	0.008			1.06	28:47	PR
1,2,3,4,6,7,8-HpCDD	0.02			0.96	31:22	—
1,2,3,4,6,7,8,9-OCDD	0.09			0.91	33:46	B_
2,3,7,8-TCDF	0.13 → 0.02 specific quantitation			0.73	19:19	—
1,2,3,7,8-PeCDF	0.03			1.32	23:53	—
2,3,4,7,8-PeCDF	0.04			1.49	24:40	—
1,2,3,4,7,8-HxCDF	0.08			1.26	27:38	PR
2,3,6,7,8-HxCDF	0.04			1.23	27:45	—
3,4,6,7,8-HxCDF	0.04			1.30	28:16	B, PR
1,2,3,7,8,9-HxCDF	0.007			1.05	28:59	—
1,2,3,4,6,7,8-HpCDF	EMPC		0.08			—
1,2,3,4,7,8,9-HpCDF	EMPC		0.02			—
1,2,3,4,6,7,8,9-OCDF	0.05			0.89	33:51	B_

Totals	Amt. (ng)	Number	DL	EMPC	Flags
Total TCDD	0.03	4		0.04	—
Total PeCDD	EMPC			0.03	—
Total HxCDD	0.03	2		0.06	—
Total HpCDD	0.05	2			—
Total TCDF	0.96	14		0.98	—
Total PeCDF	0.57	11		0.58	—
Total HxCDF	0.49	13			—
Total HpCDF	0.03	1		0.17	E_

**Affiliated Environmental Services**

TLI Project: 39931C  
 Client Sample: XAD Train XAD,IMP

Toxicity Equivalents Report  
 Analysis File: W146011

Client Project:	Brookhaven-Pennsylvania		
Sample Matrix:	M23	Date Received:	12/10/96
TLI ID:	149-70-1BDE	Date Extracted:	12/12/96
		Date Analyzed:	12/21/96
		Spike File:	SPX23704
		ICal:	WF55116
		ConCal:	W145901
Sample Size:	1.000	Dilution Factor:	n/a
Dry Weight:	n/a	Blank File:	W145817
GC Column:	DB-5	Analyst:	MM
		% Moisture:	n/a
		% Lipid:	n/a
		% Solids:	n/a

Analytes	Amt. (ng)		TEF		Equivalent
2,3,7,8-TCDD	0.002	x	1	=	0.002
1,2,3,7,8-PeCDD	0.004	x	0.5	=	0.002
1,2,3,4,7,8-HxCDD	0.004	x	0.1	=	0.0004
1,2,3,6,7,8-HxCDD	0.004	x	0.1	=	0.0004
1,2,3,7,8,9-HxCDD	0.008	x	0.1	=	0.0008
1,2,3,4,6,7,8-HpCDD	0.02	x	0.01	=	0.0002
1,2,3,4,6,7,8,9-OCDD	0.09	x	0.001	=	0.00009
TOTAL PCDD					0.00589
2,3,7,8-TCDF	0.02	x	0.1	=	0.002
1,7,8-PeCDF	0.03	x	0.05	=	0.0015
2,3,4,7,8-PeCDF	0.04	x	0.5	=	0.02
1,2,3,4,7,8-HxCDF	0.08	x	0.1	=	0.008
1,2,3,6,7,8-HxCDF	0.04	x	0.1	=	0.004
2,3,4,6,7,8-HxCDF	0.04	x	0.1	=	0.004
1,2,3,7,8,9-HxCDF	0.007	x	0.1	=	0.0007
1,2,3,4,6,7,8-HpCDF	0.08	x	0.01	=	0.0008
1,2,3,4,7,8,9-HpCDF	0.02	x	0.01	=	0.0002
1,2,3,4,6,7,8,9-OCDF	0.05	x	0.001	=	0.00005
TOTAL PCDF					0.0413

**Total EPA TEFs, 1989a: 0.0471 ng**

TLI Project: 39931C  
 Client Sample: XAD FIELD BLK

Toxicity Equivalents Report  
 Analysis File: W146012

Client Project:	Brookhaven-Pennsylvania				
Sample Matrix:	M23	Date Received:	12/10/96	Spike File:	SPX23704
TLI ID:	149-70-2	Date Extracted:	12/12/96	ICal:	WF55116
		Date Analyzed:	12/21/96	ConCal:	W145901
Sample Size:	1.000	Dilution Factor:	n/a	% Moisture:	n/a
Dry Weight:	n/a	Blank File:	W145817	% Lipid:	n/a
GC Column:	DB-5	Analyst:	MM	% Solids:	n/a

Analytes	Amt. (ng)		TEF		Equivalent
2,3,7,8-TCDD	0.004	x	1	=	0.004
1,2,3,7,8-PeCDD	0.007	x	0.5	=	0.0035
1,2,3,4,7,8-HxCDD	0.01	x	0.1	=	0.001
1,2,3,6,7,8-HxCDD	0.008	x	0.1	=	0.0008
1,2,3,7,8,9-HxCDD	0.008	x	0.1	=	0.0008
1,2,3,4,6,7,8-HpCDD	0.01	x	0.01	=	0.0001
1,2,3,4,6,7,8,9-OCDD	0.02	x	0.001	=	0.00002
TOTAL PCDD					0.0102
2,3,7,8-TCDF	0.004	x	0.1	=	0.0004
1,2,3,7,8-PeCDF	0.005	x	0.05	=	0.00025
3,4,7,8-PeCDF	0.004	x	0.5	=	0.002
1,2,3,4,7,8-HxCDF	0.006	x	0.1	=	0.0006
1,2,3,6,7,8-HxCDF	0.005	x	0.1	=	0.0005
2,3,4,6,7,8-HxCDF	0.006	x	0.1	=	0.0006
1,2,3,7,8,9-HxCDF	0.007	x	0.1	=	0.0007
1,2,3,4,6,7,8-HpCDF	0.006	x	0.01	=	0.00006
1,2,3,4,7,8,9-HpCDF	0.009	x	0.01	=	0.00009
1,2,3,4,6,7,8,9-OCDF	0.01	x	0.001	=	0.00001
TOTAL PCDF					0.00521

Total EPA TEFs, 1999a: 0.01541

## Affiliated Environmental Services

TLI Project: 39931A Method 23 PCDD/PCDF Analysis (a)  
 Client Sample: XAD Train Filter, Pr Wash Analysis File: T967929

*Front Half > 5 um particles*

Client Project:	Brookhaven-Pennsylvania		
Sample Matrix:	Fil/Rins	Date Received:	12/10/96
TLI ID:	149-70-1A,C	Date Extracted:	12/15/96
		Date Analyzed:	12/25/96
Sample Size:	1.000	Dilution Factor:	n/a
Dry Weight:	n/a	Blank File:	T967928
GC Column:	DB-5	Analyst:	BB
		% Moisture:	n/a
		% Lipid:	n/a
		% Solids:	n/a

Analytes	Amt. (ng)	DL	EMPC	Ratio	RT	Flags
2,3,7,8-TCDD	ND	0.008				---
1,2,3,7,8-PeCDD	ND	0.01				---
1,2,3,4,7,8-HxCDD	ND	0.01				---
1,2,3,6,7,8-HxCDD	ND	0.01				---
1,2,3,7,8,9-HxCDD	ND	0.01				---
1,2,3,4,6,7,8-HpCDD	EMPC		0.02			---
1,2,3,4,6,7,8,9-OCDD	0.11			0.76	34:26	---
2,3,7,8-TCDF	EMPC		0.03			---
1,2,3,7,8-PeCDF	ND	0.008				---
2,3,4,7,8-PeCDF	ND	0.008				---
1,2,3,4,7,8-HxCDF	ND	0.01				---
2,3,6,7,8-HxCDF	ND	0.008				---
3,4,6,7,8-HxCDF	EMPC		0.02			---
1,2,3,7,8,9-HxCDF	ND	0.01				---
1,2,3,4,6,7,8-HpCDF	ND	0.007				---
1,2,3,4,7,8,9-HpCDF	ND	0.01				---
1,2,3,4,6,7,8,9-OCDF	EMPC		0.05			---

Totals	Amt. (ng)	Number	DL	EMPC	Flags
Total TCDD	ND		0.008		---
Total PeCDD	EMPC			0.01	---
Total HxCDD	0.02	1			---
Total HpCDD	EMPC			0.04	---
Total TCDF	0.02	1		0.06	---
Total PeCDF	EMPC			0.02	---
Total HxCDF	EMPC			0.03	---
Total HpCDF	ND		0.009		---

**Affiliated Environmental Services**

Project Number: 39931D  
 Sample File: YN864

Method 8270A XAD, IMPINGER  
 Sample ID: XAD TRAIN TEST 1

<b>Client Project: Brookhaven, PA</b>	<b>Date Received: 12/10/96</b>	<b>Response File: YN859</b>
<b>TLI ID: 149-70-1BDE</b>	<b>Date Extracted: 12/12/96</b>	
	<b>Date Analyzed: 12/16/96</b>	
<b>Dilution Factor: 4.00</b>		

Analyte	Amount ug	FLAG	RT	Det. Limit ug	Quan. Limit ug
1,4-Dichlorobenzene-d <sub>4</sub>		IS 1	10.36		
Phenol	7.29	J	9.61		40
bis(2-Chloroethyl)ether		U		3.20	40
2-Chlorophenol		U		2.24	40
1,3-Dichlorobenzene		U		2.35	40
1,4-Dichlorobenzene		U		2.22	40
1,2-Dichlorobenzene		U		2.45	40
2,2'-oxybis(1-Chloropropane)		U		6.59	40
Benzyl alcohol		U		3.67	40
2-Methylphenol		U		2.35	40
4-Methylphenol		U		2.28	40
N-Nitroso-di-n-propylamine		U		6.58	40
Hexachloroethane		U		4.03	40
Naphthalene-d <sub>8</sub>		IS 2	12.91		
Nitrobenzene		U		3.30	40
Isophorone		U		1.63	40
2-Nitrophenol		U		3.82	40
2,4-Dimethylphenol		U		2.28	40
bis(2-Chloroethoxy)methane		U		2.24	40
2,4-Dichlorophenol		U		2.87	40
1,2,4-Trichlorobenzene		U		2.71	40
Naphthalene	10.31	BJ	12.95		40
4-Chloroaniline		U		1.67	40
Hexachlorobutadiene		U		5.04	40
4-Chloro-3-methylphenol		U		2.79	40
2-Methylnaphthalene	1.36	J	14.38		40

NA- Not Applicable; Det. Limit: Detection Limit; Quan. Limit: Quantitation Limit

IS: Internal Standard; U: Undetected; B: Present In Blank; J: Estimated- Below Quantitation Limit; E: Estimated- Above Calibration Range

**Affiliated Environmental Services**

Project Number: 39931D  
 Sample File: YN864

Method 8270A XAD, IMPINGER  
 Sample ID: XAD TRAIN TEST 1

Client Project: Brookhaven, PA      Date Received: 12/10/96      Response File: YN859  
 TLI ID: 149-70-1BDE      Date Extracted: 12/12/96  
 Date Analyzed: 12/16/96

Dilution Factor: 4.00

Analyte	Amount ug	FLAG	RT	Det. Limit ug	Quan. Limit ug
Acenaphthene-d <sub>10</sub>		IS 3	16.57		
Hexachlorocyclopentadiene		U		4.58	40
2,4,6-Trichlorophenol		U		5.18	40
2,4,5-Trichlorophenol		U		4.35	40
2-Chloronaphthalene		U		1.39	40
2-Nitroaniline		U		7.56	100
Dimethylphthalate		U		1.29	40
2,6-Dinitrotoluene		U		5.18	40
2,4-Dinitrotoluene		U		4.01	40
Acenaphthylene		U		0.85	40
4-Nitroaniline		U		4.17	100
Acenaphthene		U		1.31	40
2,4-Dinitrophenol		U		12.72	100
4-Nitrophenol		U		7.71	100
Dibenzofuran	2.36	J	17.00		40
Diethylphthalate	3.81	J	17.46		40
4-Chlorophenyl-phenylether		U		2.88	40
Fluorene		U		1.42	40
4-Nitroaniline		U		3.94	100
Phenanthrene-d <sub>10</sub>		IS 4	19.70		
4,6-Dinitro-2-methylphenol		U		7.42	100
N-Nitrosodiphenylamine		U		2.12	40
4-Bromophenyl-phenylether		U		4.18	40
Hexachlorobenzene		U		3.33	40
Pentachlorophenol		U		4.83	40
Phenanthrene	1.04	J	19.76		40

NA- Not Applicable; Det. Limit: Detection Limit; Quan. Limit: Quantitation Limit

IS: Internal Standard; U: Undetected; B: Present In Blank; J: Estimated- Below Quantitation Limit; E: Estimated- Above Calibration Range

**Affiliated Environmental Services**

Project Number: 39931D  
 Sample File: YN864

Method 8270A XAD, IMPINGER  
 Sample ID: XAD TRAIN TEST 1

<b>Client Project: Brookhaven, PA</b>	<b>Date Received: 12/10/96</b>	<b>Response File: YN859</b>
<b>TLI ID: 149-70-1BDE</b>	<b>Date Extracted: 12/12/96</b>	
	<b>Date Analyzed: 12/16/96</b>	
<b>Dilution Factor: 4.00</b>		

Analyte	Amount ug	FLAG	RT	Det. Limit ug	Quan. Limit ug
Anthracene		U		0.83	40
Di-n-butylphthalate	21.16	BJ	20.91		40
Fluoranthene		U		0.67	40
Chrysene-d <sub>12</sub>		IS 5	25.50		
Pyrene		U		0.73	40
Butylbenzylphthalate		U		1.10	40
3,3'-Dichlorobenzidine		U		2.40	40
bis(2-Ethylhexyl)phthalate	160.87	B	25.52		40
Benzo(a)anthracene		U		0.88	40
Chrysene		U		0.94	40
ylene-d <sub>12</sub>		IS 6	29.64		
Di-n-octylphthalate		U		0.52	40
Benzo(b)fluoranthene		U		0.95	40
Benzo(k)fluoranthene		U		0.96	40
Benzo(a)pyrene		U		1.18	40
Indeno(1,2,3-cd)pyrene		U		1.06	40
Dibenz(a,h)anthracene		U		1.37	40
Benzo(g,h,i)perylene		U		1.19	40

Surrogate Summary	Amount (ng)	RT	IS Ref	%REC
Phenol-d <sub>5</sub>	50.39	9.59	1	50
Nitrobenzene-d <sub>5</sub>	45.48	11.43	2	45
1,3,5-Trichlorobenzene-d <sub>3</sub>	39.89	12.12	2	40
1,4-Dibromobenzene-d <sub>4</sub>	47.54	13.01	1	48
2-Fluorobiphenyl	63.51	15.14	3	64

NA- Not Applicable; Det. Limit: Detection Limit; Quan. Limit: Quantitation Limit

IS: Internal Standard; U: Undetected; B: Present In Blank; J: Estimated- Below Quantitation Limit; E: Estimated- Above Calibration Range

**Affiliated Environmental Services**

Project Number: 39931D  
 Sample File: YN864

Method 8270A XAD, IMPINGER  
 Sample ID: XAD TRAIN TEST 1

Client Project: Brookhaven, PA	Date Received: 12/10/96	Response File: YN859
TLI ID: 149-70-1BDE	Date Extracted: 12/12/96	
	Date Analyzed: 12/16/96	

Dilution Factor: 4.00

Surrogate Summary	Amount (ug)	RT	IS Ref	%REC
2,4,6-Tribromophenol	96.21	18.22	3	96
Anthracene-d <sub>10</sub>	78.09	19.81	4	78
Pyrene-d <sub>10</sub>	96.96	22.69	5	97
Terphenyl-d <sub>14</sub>	107.60	23.05	5	108

viewed by Pas Date 12/18/96

NA- Not Applicable; Det. Limit: Detection Limit; Quan. Limit: Quantitation Limit

IS: Internal Standard; U: Undetected; B: Present In Blank; J: Estimated- Below Quantitation Limit; E: Estimated- Above Calibration Range



# TEST RESULTS

		RUN #1						
METHOD 26A								
HCL (mg/dscm)			61.29					
CL (mg/dscm)			172.28					

$$\text{mg/dscm} \quad C = \frac{\text{Khcl}}{\text{Vmstd}}$$

C = Concentration of HCL in the stack gas, mg/dscm.

Khcl = Total concentration collected in the sampling train, mg.

Vmstd = Volume of gas sample as measured by the dry gas meter, corrected to dry standard conditions, dscm.



# TEST RESULTS

Front Half

RUN #1

METHOD 29

Antimony (mg/dscm)	0.000116	→ Less than Limit of Detection Limit.
Arsenic (mg/dscm)	0.005088	
Barium (mg/dscm)	0.001457	
Beryllium (mg/dscm)	0.000093	→ Less than Limit of Detection Limit.
Cadmium (mg/dscm)	0.104866	
Chromium (mg/dscm)	3.972389	
Copper (mg/dscm)	0.218759	
Lead (mg/dscm)	0.307305	
Mercury (mg/dscm)	2.66E-06	→ Less than Limit of Detection Limit.
Nickel (mg/dscm)	0.179174	
Selenium (mg/dscm)	2.31E-07	→ Less than Limit of Detection Limit.
Silver (mg/dscm)	0.023265	
Sodium (mg/dscm)	4.340460	
Titanium (mg/dscm)	0.035418	
Zinc (mg/dscm)	1.69104	

$$\text{mg/dscm} \quad C_s = \frac{M_t \cdot K_4}{V_{mstd}}$$

Cs = Concentration of a metal in the stack gas, mg/dscm.

K4 = 10-3 mg/ug.

Mt = Total mass of that metal collected in the sampling train, ug.

Vmstd = Volume of gas sample as measured by the dry gas meter, corrected to dry standard conditions, dscm.



# TEST RESULTS

Back Half

RUN #1

**METHOD 29**

Antimony (mg/dscm)	0.000116
Arsenic (mg/dscm)	0.000206
Barium (mg/dscm)	0.001205
Beryllium (mg/dscm)	0.000093
Cadmium (mg/dscm)	2.951513
Chromium (mg/dscm)	1.711877
Copper (mg/dscm)	0.432657
Lead (mg/dscm)	0.361126
Mercury (mg/dscm)	0.002149
Nickel (mg/dscm)	1.871606
Selenium (mg/dscm)	0.000130
Silver (mg/dscm)	0.000023
Sodium (mg/dscm)	1.746601
Sulfur (mg/dscm)	61.96
Titanium (mg/dscm)	0.023265
Zinc (mg/dscm)	17.91742

Less than Limit of Detection Limit.

Less than Limit of Detection Limit.

Less than Limit of Detection Limit.

$$\text{mg/dscm } C_s = \frac{\text{Mt} \cdot K_4}{V_{mstd}}$$

$C_s$  = Concentration of a metal in the stack gas, mg/dscm.

$K_4$  = 10<sup>-3</sup> mg/ug.

$Mt$  = Total mass of that metal collected in the sampling train, ug.

$V_{mstd}$  = Volume of gas sample as measured by the dry gas meter, corrected to dry standard conditions, dscm.



# TEST RESULTS

Front Half

RUN #1

METHOD 8080	
mg/dscm	
Aroclor 1016	0.000142
Aroclor 1221	0.000142
Aroclor 1232	0.000142
Aroclor 1242	0.000142
Aroclor 1248	0.000142
Aroclor 1254	0.000142
Aroclor 1260	0.000142

Results were less than Limit of Detection limit.

Back Half

RUN #1

METHOD 8080	
mg/dscm	
Aroclor 1016	0.000283
Aroclor 1221	0.000283
Aroclor 1232	0.000283
Aroclor 1242	0.000283
Aroclor 1248	0.000283
Aroclor 1254	0.000283
Aroclor 1260	0.000283

Results were less than Limit of Detection limit.



# TEST RESULTS

Back Half

RUN #1

METHOD 8080 (Pesticides)	mg/dscm
alpha - BHC	0.000014
alpha-Chlordane	0.000014
Aldrin	0.000014
beta-BHC	0.000014
delta-BHC	0.000014
4,4' -DDD	0.000028
4,4' -ODE	0.000028
4,4' -DDT	0.000028
Dieldrin	0.000028
Endrin	0.000028
Endrin Aldehyde	0.000028
Endosulfan I	0.000014
Endosulfan II	0.000028
Endosulfan sulfate	0.000028
gamma-BHC (Lindane)	0.000014
gamma-Chlordane	0.000014
Heptachlor	0.000014
Heptachlor epoxide	0.000014
Methoxychlor	0.000142
Toxaphene	0.001417

Results were less than Limit of Detection limit.